SOIL-PLANT RELATIONSHIPS IN THE STABILIZED SAND DUNES OF NORTHWESTERN OKLAHOMA

By

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LIST OF ABBREVIATIONS

Scr - Sporoblus cryptandrus (sand dropseed)

Bgr - Bouteloua gracilis (Blue grama)

Pst - Paspalum stramineum (sand paspalum)

Par - Poa arachnifera (Texas bluegrass)

Pvi - Panicum virgatum (switchgrass)

Aha - Andropogon hallii (sand bluestem)

Etr - Eragrostis trichodes (sand lovegrass)

Asc - Andropogon scoparius (little bluestem)

K - Potassium

CEC - cation exchange capacity

OM - organic matter

Na -- Sodium

Ca - Calcium

Mg - Magnesium

Fs - fine sand

Vfs - very fine sand

Ms - medium sand

Cs - coarse sand

Vcs - very coarse sand

Qz - Quartz

Fs - Feldspars

CHAPTER I

INTRODUCTION

It was noticed that the stabilized sand dunes of Northwestern Oklahoma have an interesting pattern in the plant communities. On the east-west facing slopes of the dunes, plant communities vary sharply from one slope position to another. With this in mind, pedons were allocated along a transect according to the variations in vegetation and slope position. Two sites were chosen randomly out of 13 sites to be the study areas. A total of 12 pedons were described and sampled from both areas.

The main objectives of this study are: (1) to help explain the variations in plant communities and soils within the sandy ecotones; (2) to obtain insight on soil genesis and soil-plant relationships; and (3) to help define soil mapping units in sandy areas. To reach such a compound objective, all soil properties that can be measured or noticed in the field were gathered and used. Vegetation also was studied, including species identification and counting of each species present. Two statistical methods were used, namely the canonical correlation and cluster analysis. A high speed computer was used in handling the data for the statistical analysis.

This research is subdivided into seven chapters. The first chapter deals with general introduction, the second one deals with methods and materials, the third one deals with canonical correlation technique, the fourth chapter deals with soil-plant relationships in the stabilized sand dunes of Northwestern Oklahoma; the fifth chapter deals with soil genesis, morphology, and the mapping units of stabilized sand dunes and the cluster analysis; the sixth chapter deals with clay mineralogy of some selected soils of the dunes; and the seventh chapter deals with relief and its effect on soil-moisture and temperature profiles within the stabilized sand dunes. Some of these chapters will be manuscripts prepared for publication in the Agronomy Journals after minor modifications.

The study area of this research is located in the southwest corner of Section 28, T. 25 N., R. 22 W., Harper County, Oklahoma. Published Soil Survey, Sheet No. 115.

CHAPTER II

METHODS AND MATERIALS

Thirteen sites were selected and numbered according to differences in plant communities within each one and all having east-west facing slopes. Two of them were selected randomly to be the study areas. A trench was opened from the summit-to-summit in one of the two selected sites in order to describe and sample the soils. Six pedons were selected, described, and sampled from each site according to the variation in vegetation and aspect of the slope. Duplicate samples were obtained in the field instead of running duplicates in the lab.

Field Work

Vegetation Study

The vegetation studies were conducted in detail in a cross section along each site in a line parallel to the sampled pedons. Plant species were identified and counted in each position using a 2 m^2 metal square. This study, along with moisture and temperature measurements, was done with the cooperation of the Woodward Experiment Station.

Morphological Study

Soil pedons were described morphologically in the field using a special format to record information, including most of the morphological properties than can be noticed or determined (Figure 2.1, which has been used by Dawud, 1979).

Moisture and Temperature Study

Moisture studies were conducted by using a neutron probe meter as described by Van Barel et al. (1963). Seven neutron probe metal tubes were installed along with the positions of the selected pedons. Moisture content readings were taken each 20 cm depth intervals to a total depth of 440 cm. Readings were about two weeks apart for the entire growing season of 1978. Positions of the tubes, as well as the position of the pedons, are shown in Figure 2.2. Slope positions were identified according to Ruhe et al. (1968). Using thermocouples, two temperature readings were taken, one at 15 cm depth and the other at 50 cm depth in the same positions of the selected pedons. Readings of the soil temperature were taken at the same time as the moisture readings were taken and for the same period.

Laboratory Work

Samples were numbered randomly and the Slipped-Block design was used (Timon, 1962). Due to the misuse of the design in the lab, each duplicate sample was averaged and used in the statistical analysis.

Chemical Analysis

Samples were air-dried and passed through a two millimeter sieve.

Mechanical analysis was done as described by Grossman (1961) for particle size fractionation. Organic matter was removed by heating the soil with 31% hydrogen peroxide in a water bath (Jackson, 1956). Due to

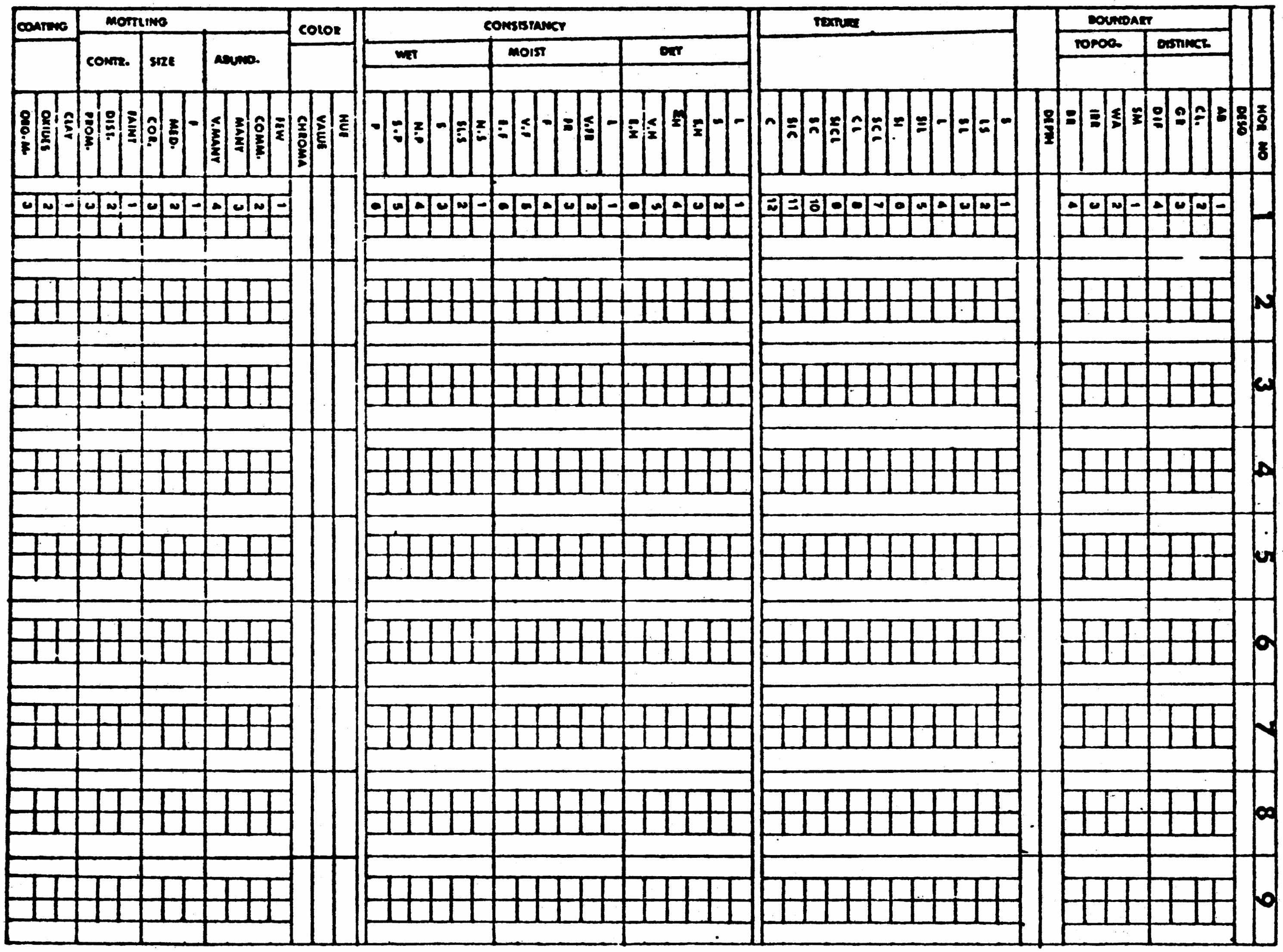
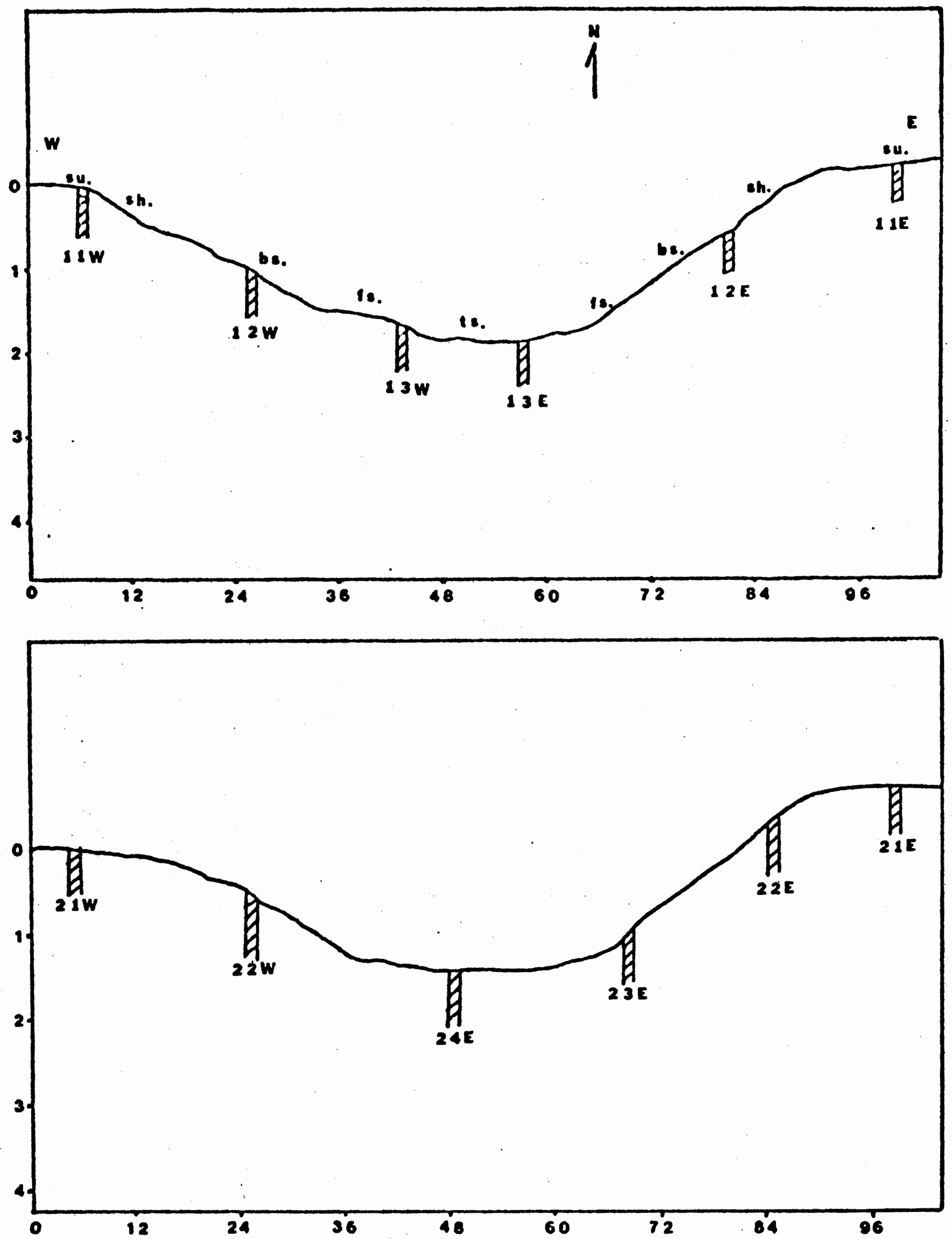


Figure 2.1. Field Sheet Showing the Coding System of the Morphological Properties.

CONCRETION	COLOR	BLACK	1
		WHITE	2
	QUAT	FEW	1
		COMM.	2
		MANY	3
	SIZE	FINE	1
		MED.	2
		COAR.	3
STRUCTURE	CLASS	V.F.	1
		F.	2
		MED.	3
		COAR.	4
		V.COAR.	5
	GRADE	STR.	1
		V.WEAK	2
		W.	3
		MOD.	4
		STROG	5
		V. STR.	6
	TYPE	PRISM.	1
		COLUM.	2
		SBK.	3
		ABK.	4
		GRAN.	5
		PLATT.	6
ROOT	SIZE	F.	1
		MED.	2
		COAR.	3
	QUANT	FEW	1
		COMM.	2
		MANY.	3
PORES	SIZE	V. F.	1
		F.	2
		MED.	3
		COAR.	4
	ORIENT	HOR.	1
		VER.	2
		RAND.	3
		OBLIQ.	4

AREA	
DATE	
LOCATION	
SLOPE	
D. DAR.L YER	
D. BUR. L	
D.90% ROOT	
D.CROTO.	
D.CONCR.	
D. MOTT.	
D. B.W. BOD.	
D.SLKSID.	
D.C L.FLM.	
D. PE.FACE	
D. STR	
DRAINGE	
V. P.	1
P.	2
S.P.	3
MOD.W.	4
W.	5
S.EX.	6
EX.	7
PERMEAB.	
V. S.	1
S.	2
MED.	3
RAP.	4
P. SAMPLED	✓

Figure 2.1 (Continued)



su. = summit; sh. = shoulder; bs. = backslope; fs. = foot slope; and ts. = toe slope positions

Figure 2.2. Location of the Selected Pedons of Area One and Area Two with Slope Positions.

the several treatments done on the soil samples, a dispersing agent, sodium hexa-meta phosphate, was added to the samples. Clay was measured by the hydrometer method (Day, 1965). Very coarse sand, coarse sand, medium sand, fine sand, and very fine sand fractions were separated by appropriate sieves and measured. Using a fresh sample, organic matter was measured by determination of organic carbon using potassium dicromate oxidation procedure as described by Schollenberger (1931). Cation exchange capacity was determined by saturating the soil with sodium acetate,pH 8.2 (Bower, 1952). Extractable cations (Ca^{++}, Mg^{++}, K^{+}, and Na^{+}) were determined by using ammonium acetate procedure (Soil Survey Staff, 1972). Calcium and magnesium were determined by the 0.01 N EDTA titration method of Richards (1954). Sodium and potassium were measured with a Perkin Elmer 403 Atomic Absorption spectrophotometer. Soil pH was measured by Beckman pH meter on a 1:1 soil to water suspension.

Mineralogical Analysis

Samples were collected from two areas of sand dunes referred to as Ecotone 1 and Ecotone 2. The samples represent A, B, and C horizons in each profile. Soil profiles represent summits and toe slope positions. Soil samples were air-dried and passed through a two millimeter sieve. Carbonates and soluble salts content were removed from undisturbed soil samples by treatment with sodium acetate pH 5, organic matter content was removed by using 30% H_2O_2 oxidation method (Jackson, 1956). Removal of iron oxides was done by using the citrate-dithionite method (Kittrick and Hope, 1963). Due to the several treatments done on the samples, a dispersing agent, citrate buffer, was added to the samples. Separation of clay fractions was done by using a high speed centrifuge. To separate the 2 microns fractions, the suspension was centrifuged at 750 rpm for about 5.3 minutes as a sedimentation time (Kittrick and Hope, 1963).

An oriented clay sample for X-ray diffraction analysis was prepared by addition of clay suspension to a porous ceramic slide mounted on a vacuum device for removal of excess moisture. X-ray diffraction was obtained on a natural sample, an ethylene glycol-solvated sample, and heated to 500^{o}C for one hour, using a General Electric XRD 6 instrument with Ni-filter CuKα at 30 KVP at 20 MA. The quarts-feldspars percentage was determined by Beke line immersion method in the dominant sand fraction of each sample.

CHAPTER III

CANONICAL CORRELATION

Abstract

The vegetation data were selected to be the main group of variables in the canonical correlation technique. Ten dominant plant species were chosen and subdivided into three main sets. The chemical and physical data were used as the other group of variables. It was subdivided into five main groups. Canonical correlation was done with each set and group separately until all possible combinations were reached. Soil-moisture and temperature data also were used as another separate group of variables. Due to the differences in the number and the sequence of the genetic horizons, they were subdivided into four main horizons. A horizons, which exist in all locations, followed by B horizons, which are mainly B1 and B2 horizons. The Bt horizons for each location were represented in the canonical correlation by the weighted Bt horizons, in which each soil property was weighted by thickness. The locations with more than one C horizon were treated the same way as the weighted Bt horizons. After such a weighing procedure, the two sites of the study area had a total of 12 A horizons, 12 B horizons, 7 Bt horizons, and 10 C horizons. A significant and close association was found between counts of different plant species and different variables of soil chemical and physical properties.

Introduction

The canonical correlation technique was introduced by Hoteling (1936) to understand the possible relationships between two sets of variables. A simple correlation coefficient (pairwise correlation) was used in this study to find the relationships between percentage counts of different plant species and different chemical and physical soil properties of the two sites. Due to the small number of observations, especially that of the Bt horizons, 7 observations, it was quite impossible to use all the variables at one time.

For example, Sgr (sand dropseed), Bgr (blue grama), Asc (little bluestem), and Aha (sand bluestem) were correlated with thickness, pH, and organic matter as the first set with the first group of variables. Then the same set of vegetation variables were correlated with the second group, the third group, the fourth group, and the fifth group of chemical variables each at one time, separately. Table 3.1 shows the rest of the different sets and groups of variables and their combinations.

As summarized by Dawud (1979), the canonical variate, especially the first one, has another property besides displaying maximum correlation. That property is the maximum variance.

No attempts will be made in this chapter to describe the theories behind the canonical correlation technique. The main objective is to show the different correlations between soil variables and different plant species.

Results and Discussion

A total of eleven vegetation species and fourteen chemical soil properties were used in a total of 15 sets of combinations. The first

TABLE 3.1

THE DIFFERENT SETS AND GROUPS OF VARIABLES AND THEIR COMBINATIONS USED IN THE CANONICAL CORRELATION TECHNIQUE

		1st Group	2nd Group	3rd Group	4th Group	5th Group
Plant Species		Thickness/pH/OM	Ca/Mg/K	Na/CEC/Clay	Vcs/Cs/Ms	Fs/Vfs
Scr (Sand dropseed) Bgr (Bluegrama) Asc (Little bluestem) Aha (Sand bluestem)	1st set	1	4	7	10	13
Pvi (Switch grass) Etr (Sand lovegrass) Pst (Sand paspalum) Par (Texas blue grass)	2nd set	2	5	8	11	14
Other grasses Forbs Shrubs	3rd set	3	6	9	12	15*

15* - Number of different combinations for each horizon.

set II composed of Scr, Bgr, Asc, and Aha as the vegetation variables and thickness of the horizon, pH, and organic matter as the chemical variables. The same set of vegetation variables were repeated with Ca, Mg, and K as the second group, with Na, CEC, and Clay as the third group, with Vcs, Cs, and Ms as the fourth group, and with Fs, Vfs as the fifth group (Table 3.1). All conclusions will be based on 0.05 confidence interval.

The second set of vegetation was composed mainly of Pvi, Etr, Pst, and Par. The third set of vegetation was other grasses, forbs, and shrubs. The same chemical data variables were applied in five different groups with each of the second and the third sets of vegetation. This was repeated for each horizon (A, B, Bt, and C horizons).

A-Horizons

First Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with thickness, pH, and OM. The canonical correlation of the first variates of this set was .86 (Table 3.2) (Prob>Chi-Sq = .2644). This can be interpreted as high Scr values (.70), low Bgr values (-.33), and low Aha values (-.66) are highly associated with low thickness values (-.70), low pH values (-.54), and low OM values (-.09) (Figure 3.1). In terms of the original data, it can be interpreted as low counts of Scr, high counts of Bgr, and high counts of Aha are highly correlated with thicker A horizons, high pH values, and high organic matter content.

The Second Set of Variables. Pvi, Etr, Pst, Par with thickness, pH, and OM. The canonical correlation of the first variates of this set

TABLE 3.2

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS,
FIRST GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.58015978	-4.52754779	0.85569862	14.58512	12	0.2644
2	0.42172350	-1.63201787	0.52533694	4.04440	6	0.6728
3	0.75077381	-3.55918251	0.40252766	1.41417	2	0.4975

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	0.558000	-0.329941	0.157476	-0.655906
VAR # 2	-0.337738	-0.492460	0.525150	0.701613
VAR # 3	0.501357	0.304359	-0.498210	0.215179

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	CM
VAR # 1	-0.694917	-0.540233	-0.086372
VAR # 2	0.001223	-0.497606	0.730235
VAR # 3	0.719089	-0.678624	-0.677715

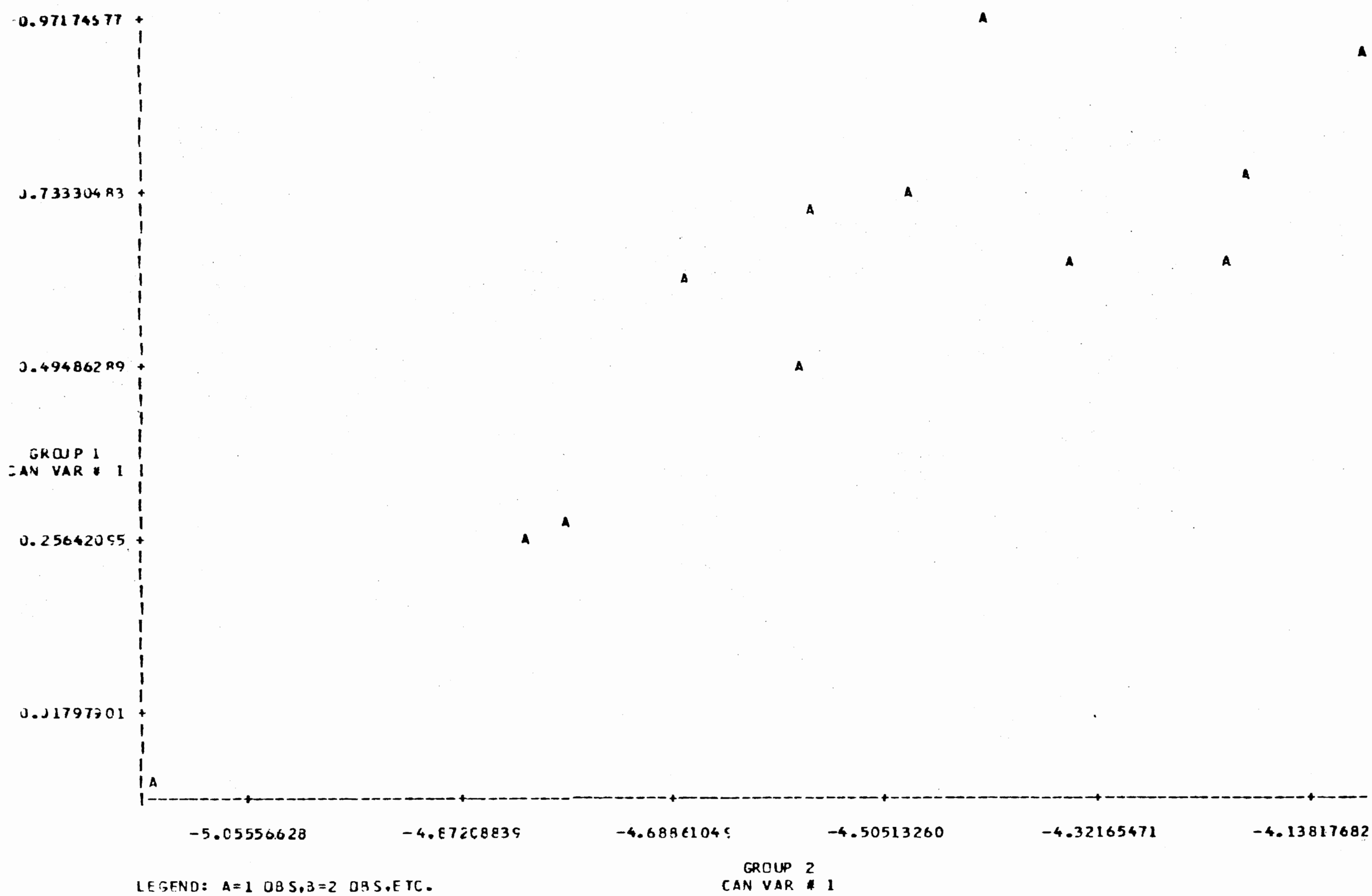


Figure 3.1. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, First Group, First Set of Variables.

was .91 (Table 3.3) (Prob>Chi-Sq = .135). This can be interpreted as high Etr values (.81), and moderately high Pvi values (.52) which are highly associated with high OM values (.74), moderately high pH values (.38), and very low thickness values (-.88) (Figure 3.2). In terms of the original data, the thickness has little or no effect on the counts of Etr and Pvi.

<u>The Third Set of Variables</u>. Other grasses, forbs, and shrubs with thickness, pH, and OM. The canonical correlation of the first variates of this set was .71 (Table 3.4) (Prob>Chi-SQ = .4057). This can be interpreted as very high other grasses values (.93), and very high forbs values (.88) are moderately associated with high thickness values (.81), low pH values (-.59), and low OM values (.66) (Figure 3.3). The only pattern, in terms of the original data, is high other grasses and high forbs counts are highly correlated with low pH and moderately low organic matter content.

Second Group

<u>The First Set of Variables</u>. Scr, Bgr, Asc, Aha with Ca, Mg, and K. The canonical correlation of the first variates of this set was .88 (Table 3.5) (Prob>Chi-SQ = .0350). This can be interpreted as moderately high Aha values (.49) with low Bgr values (-.44) are highly associated with very low Mg value (-.96) and low Ca values (-.44) (Figure 3.4). In another way, a low count of Aha and high counts of Bgr are well correlated with high values of Ca and Mg.

<u>The Second Set of Variables</u>. Pvi, Etr, Pst, Par with Ca, Mg, and K. The canonical correlation of the first variates of this set was .97

TABLE 3.3

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, FIRST GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.53155729	1.66657847	0.51312770	17.14944	12	0.1435
2	0.30836551	-5.66175700	0.54174390	2.79283	6	0.9355
3	0.34870874	0.99514069	0.04110227	0.01353	2	0.9821

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.518090	0.811392	0.007385	0.330503
VAR # 2	-0.288019	0.278749	0.912273	-0.690915
VAR # 3	-0.169316	-0.363771	0.376424	0.515617

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	OM
VAR # 1	-0.881099	0.380447	0.743918
VAR # 2	-0.405675	-0.812203	-0.179608
VAR # 3	-0.243092	0.442252	-0.644076

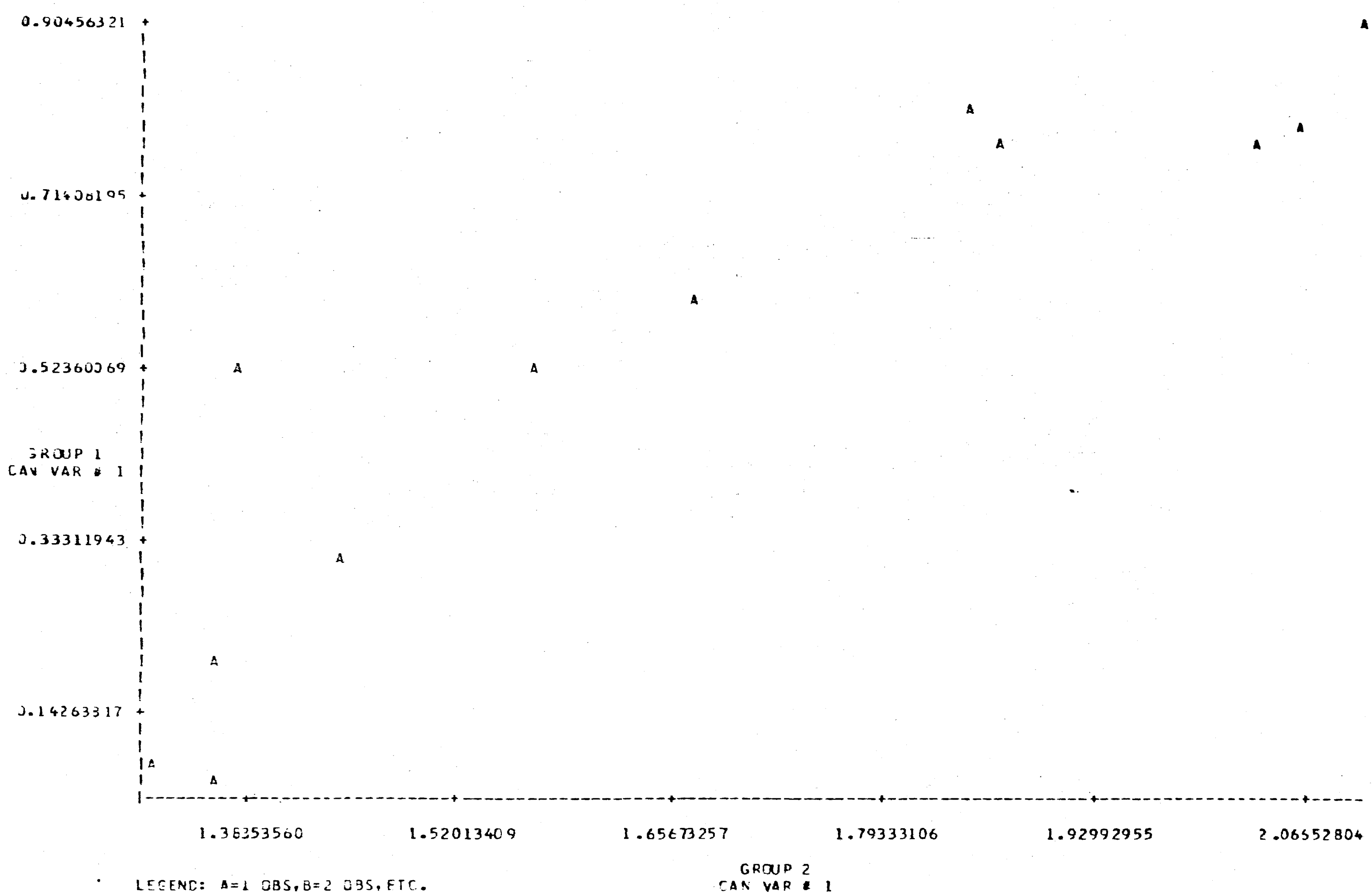


Figure 3.2. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, First Group, First Set of Variables.

TABLE 3.4

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS,
FIRST GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.47122917	-2.83000931	0.70962944	9.35011	9	0.4057
2	0.08124251	-5.06769114	0.57393222	3.39738	4	0.4956
3	0.62321691	1.39154504	0.01059634	0.00095	1	0.9252

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.230374	0.877984	0.093464
VAR # 2	0.276638	0.131439	0.984226
VAR # 3	-0.240573	0.460292	0.150214

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	OM
VAR # 1	0.914818	-0.586418	-0.662825
VAR # 2	-0.479763	-0.807238	0.245450
VAR # 3	0.326892	-0.066935	0.707402

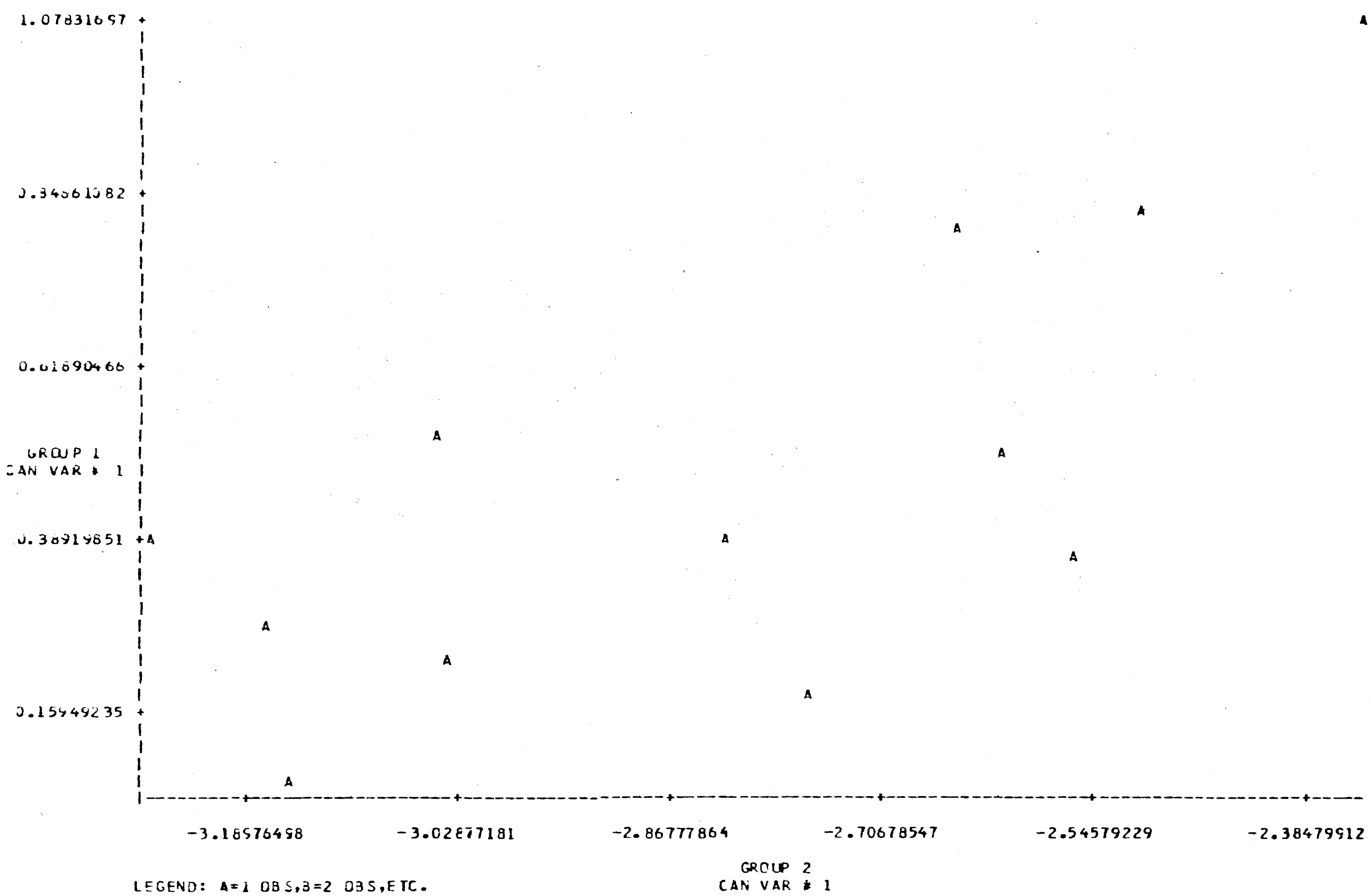


Figure 3.3. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, First Group, Third Set of Variables.

TABLE 3.5

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, SECOND GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.75048329	-0.91422019	0.87732248	22.22164	12	0.0350
2	0.16192354	2.83976684	0.81795602	10.47484	6	0.1051
3	0.60201726	-0.16160319	0.42916182	1.62849	2	0.4464

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BSR	ASC	AHA
VAR # 1	0.271288	-0.444015	-0.032547	0.486948
VAR # 2	-0.228550	-0.362350	0.854852	-0.105113
VAR # 3	-0.094379	0.813767	0.442338	0.394308

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	-0.437863	-0.955300	-0.124689
VAR # 2	0.392729	0.184211	0.904776
VAR # 3	0.808727	0.231230	0.407226

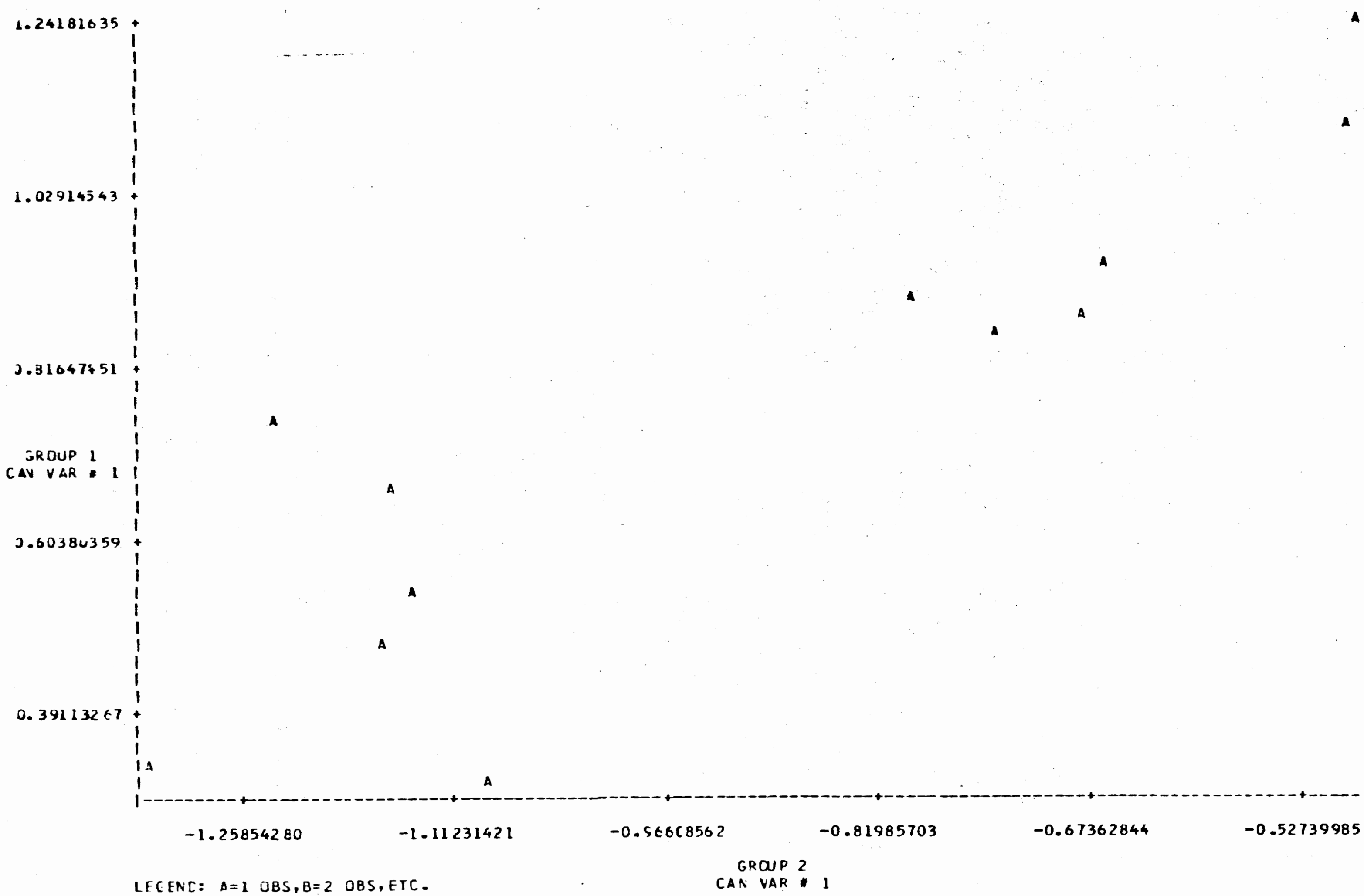


Figure 3.4. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Second Group, First Set of Variables.

(Table 3.6) (Prob>Chi-SQ = .0014). This can be interpreted as high Par values (.82) and high Pvi values (.84) are highly associated with high Ca values (.96), high Mg values (.79), and high K values (.81) (Figure 3.5). This can be interpreted in terms of the original data as high counts of Par and Pvi correspond to high Ca, Mg, and K values.

<u>The Third Set of Variables</u>. Other grasses, forbs, and shrubs with Ca, Mg, and K. The canonical correlation of the first variates of this set was .80 (Table 3.7) (Prob>Chi-SQ = .3418). This can be interpreted as high other grasses values (.83) are highly associated with low Ca values (-.70) (Figure 3.6). In terms of the original data, a high count of other grasses corresponds to low Ca values.

<u>Third Group</u>

<u>The First Set of Variables</u>. Scr, Bgr, Asc, and Aha with Na, CEC, and Clay. The canonical correlation of the first variates of this set was .72 (Table 3.8) (Prob>Chi-SQ = .6217). This can be interpreted as high Bgr values (.55) and high Asc values (.65) are moderately associated with very high CEC values (1.0) (Figure 3.7). In terms of the original data, as CEC increases the Asc and Bgr counts increase.

<u>The Second Set of Variables</u>. Pvi, Etr, Pst, and Par with Na, CEC, and Clay. The canonical correlation of the first variates of this set was .87 (Table 3.9) (Prob>Chi-SQ = .1324). This can be interpreted as high Par values (.92) and high Pvi values (.75) are highly associated with very high CEC values (.91) and moderately low Na values (-.41) (Figure 3.8). The best example, in terms of the original data, is in 13E, where high counts of Par (19.0) and high counts of Pvi (2.3) are

TABLE 3.6

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, SECOND GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.36655523	1.93318685	0.96858533	32.19545	12	0.0014
2	-0.01567093	-2.18056153	0.82064934	9.93013	6	0.1266
3	0.11601405	-0.55888534	0.33895867	0.97637	2	0.6196

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.844840	0.260198	-0.253955	0.819982
VAR # 2	-0.455988	-0.338352	-0.244582	0.454947
VAR # 3	-0.231679	0.867379	-0.217012	-0.320839

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	0.964720	0.787054	0.808019
VAR # 2	0.156122	0.245468	-0.548798
VAR # 3	0.211994	-0.565935	0.214304

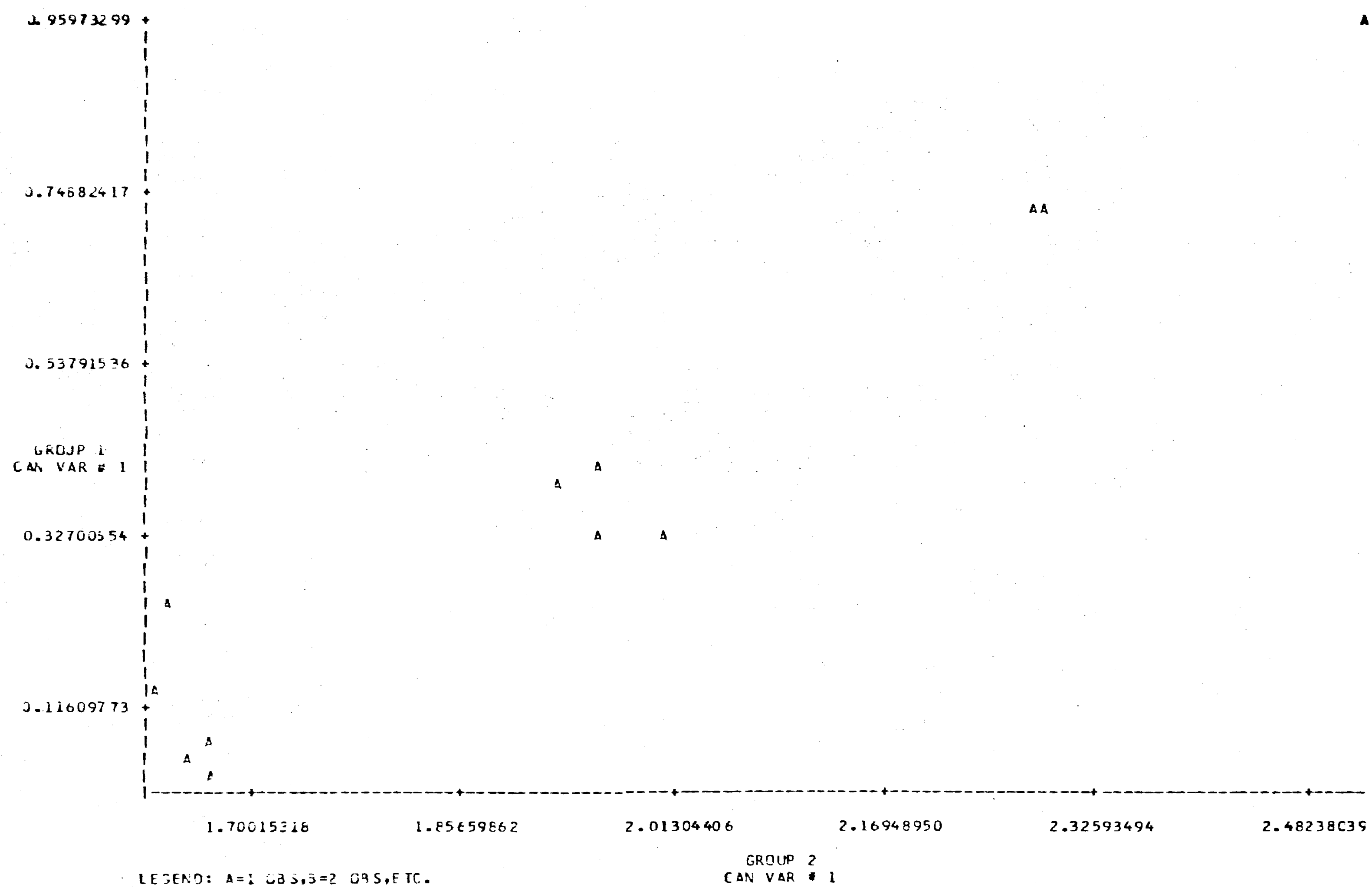


Figure 3.5. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Second Group, Second Set of Variables.

TABLE 3.7

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, SECOND GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.11677395	0.42111379	0.80208178	10.10513	9	0.3418
2	0.52355054	0.79517421	0.38192604	1.34198	4	0.8552
3	0.57344936	-2.84783666	0.01453106	0.00179	1	0.9181

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.825798	0.250732	0.364360
VAR # 2	0.503903	0.763339	-0.405529
VAR # 3	0.253257	0.595354	0.829345

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	-0.702792	-0.049200	-0.346744
VAR # 2	-0.258522	-0.724256	0.331986
VAR # 3	-0.662759	-0.687764	-0.677242

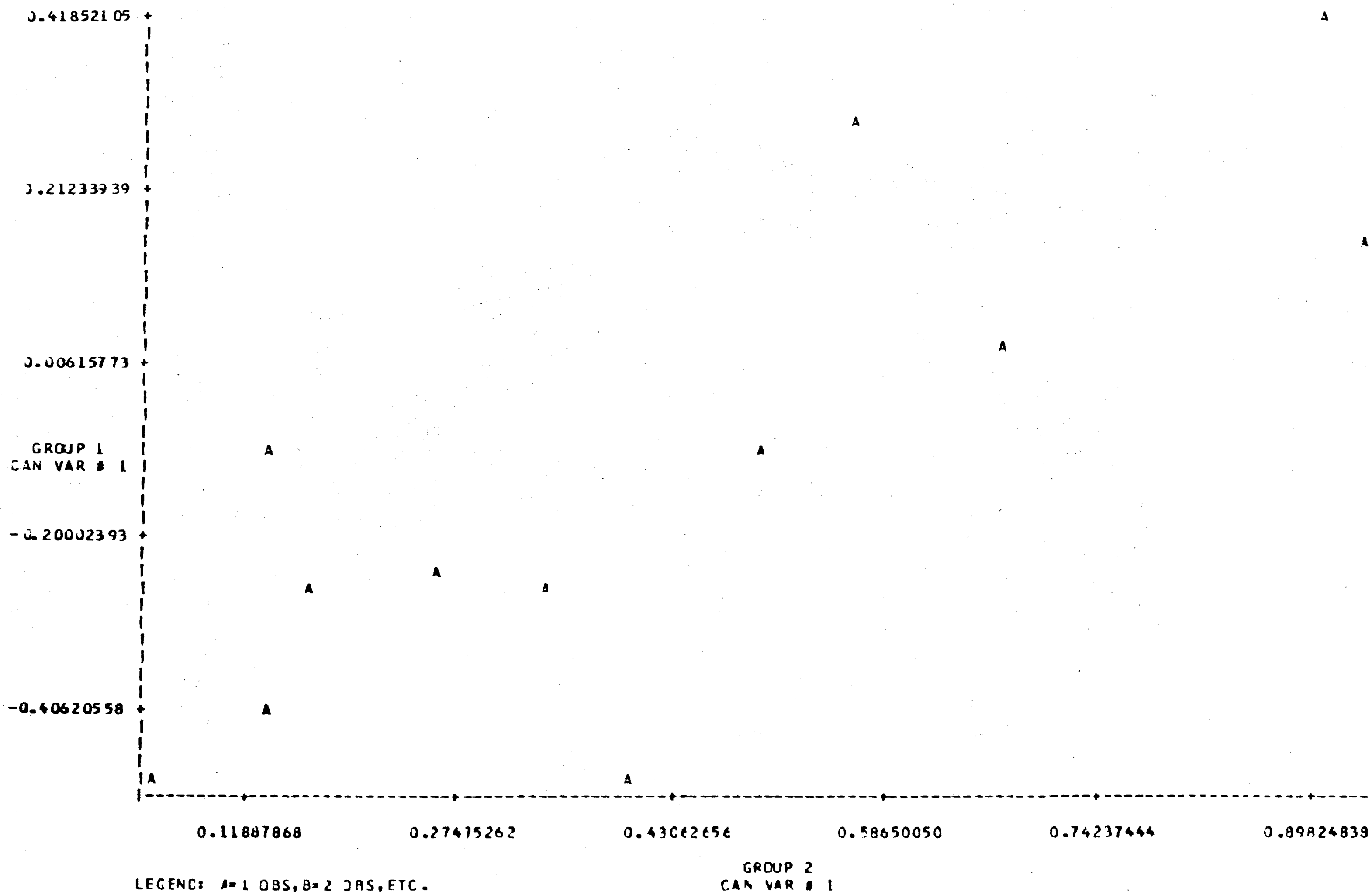


Figure 3.6. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Second Group, Third Set of Variables.

TABLE 3.8

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, THIRD GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.50927907	1.92212288	0.72157223	9.94532	12	0.6217
2	-0.30133345	-1.31151982	0.54473319	4.05281	6	0.6717
3	0.13936264	-0.57615280	0.37845131	1.23664	2	0.5441

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	0.106376	0.553492	0.652389	-0.225672
VAR # 2	-0.291729	0.565808	-0.282428	-0.249727
VAR # 3	0.872770	-0.160907	-0.557951	-0.883434

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	-0.181224	0.994432	0.163781
VAR # 2	-0.559800	0.094751	-0.900643
VAR # 3	-0.808567	-0.046125	0.402514

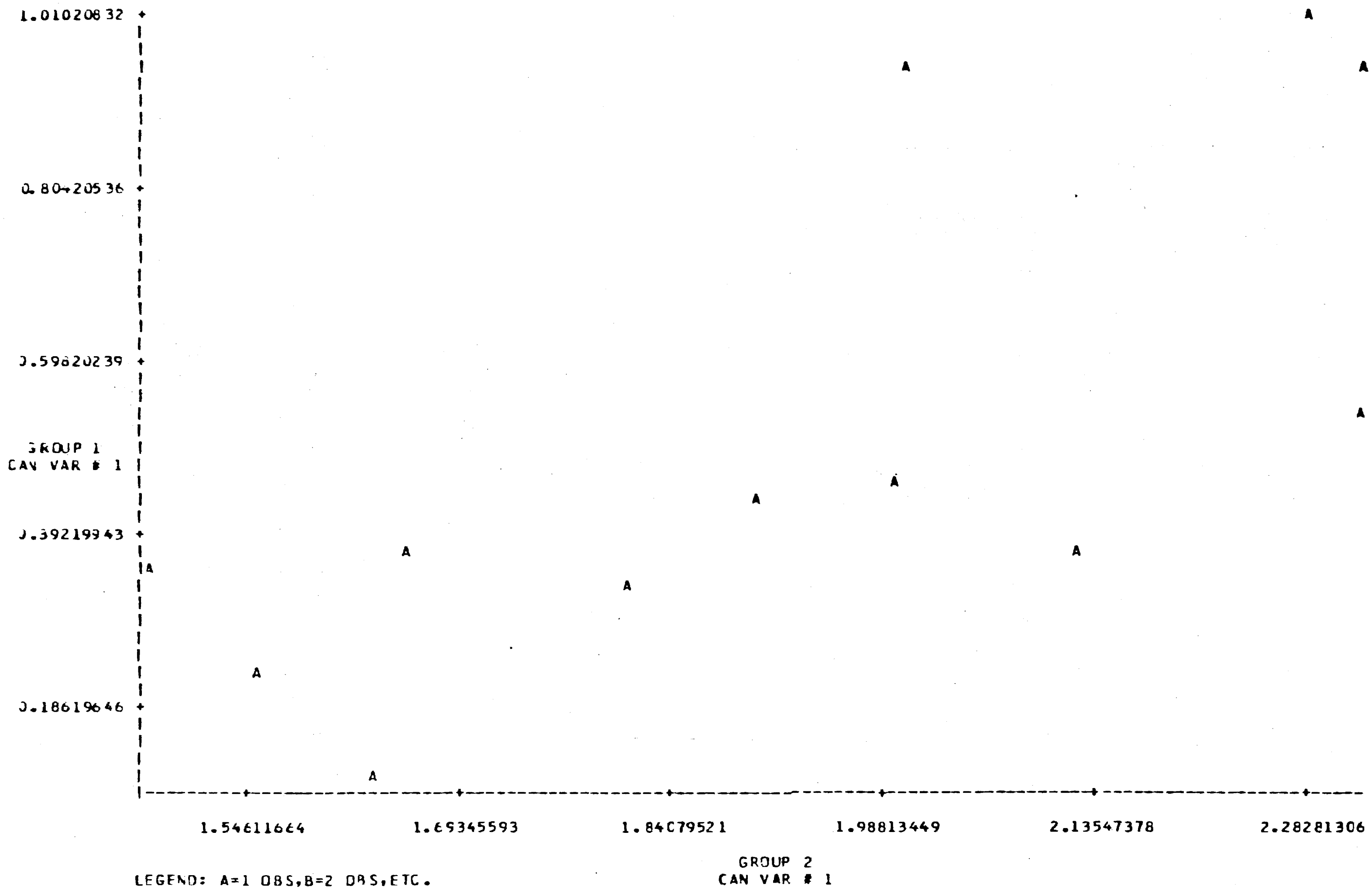


Figure 3.7. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Third Group, First Set of Variables.

TABLE 3.9

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, THIRD GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.32037375	1.02500285	0.86877094	17.46442	12	0.1324
2	0.33137634	-1.34691519	0.72548007	6.22018	6	0.3993
3	0.45956428	1.65515937	0.17274762	0.24237	2	0.8814

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	EIR	PST	PAR
VAR # 1	0.749005	0.119151	-0.326425	0.920011
VAR # 2	-0.049177	-0.469221	0.774569	0.155546
VAR # 3	0.306457	0.789215	0.526597	-0.359357

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	-0.406371	0.909525	-0.323652
VAR # 2	-0.913410	-0.160532	0.005010
VAR # 3	0.023351	0.374396	0.946163

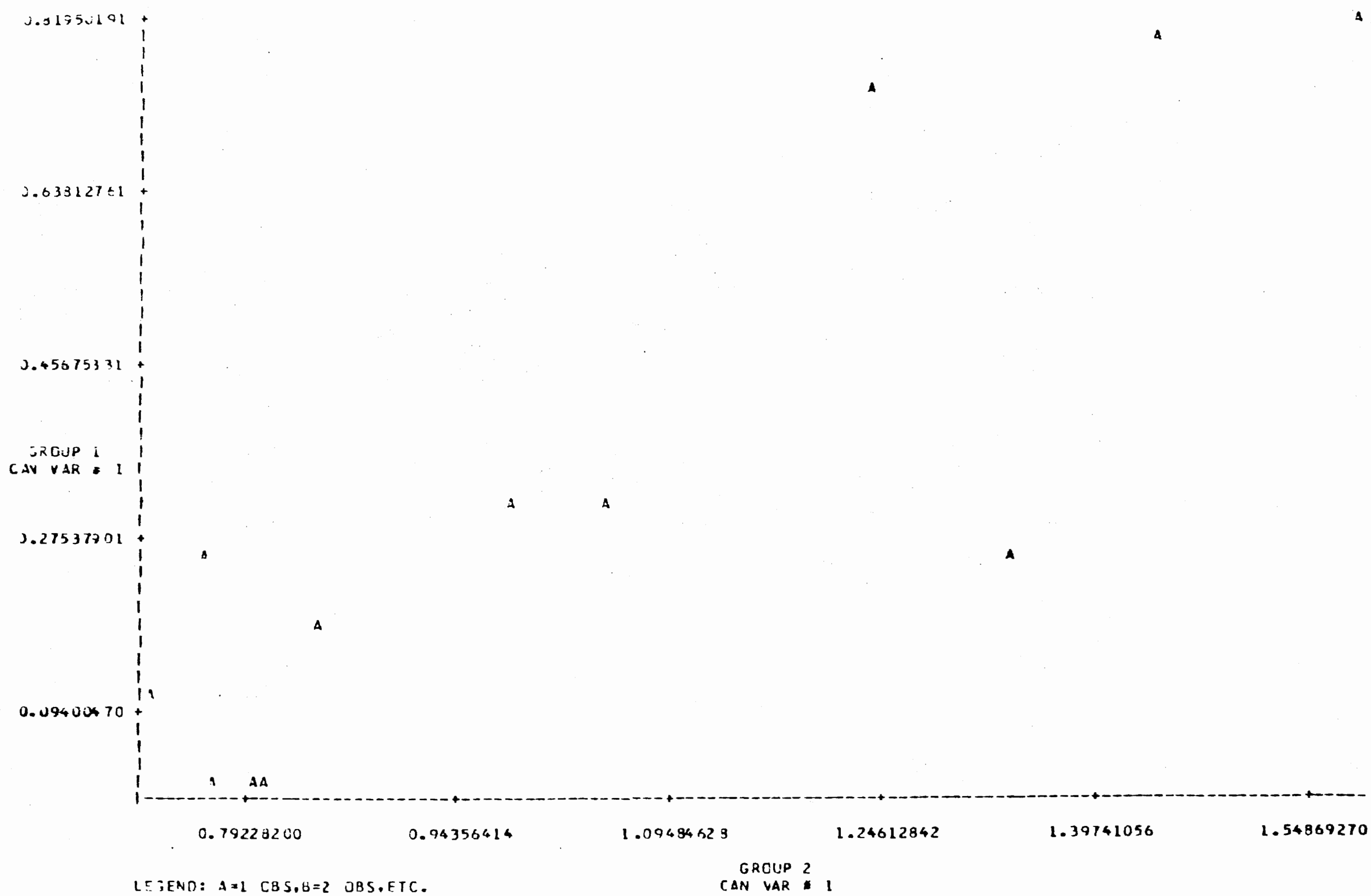


Figure 3.8. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Third Group, Second Set of Variables.

associated with high CEC in the A horizons of that location (5.28 meq/ 100 gm).

The Third Set of Variables. Other grasses, forbs, and shrubs with Na, CEC, and Clay. The canonical correlation of the first variates of this set was .84 (Table 3.10) (Prob>Chi-SQ = .1429). This can be interpreted as high other grasses values (.68), high forbs values (.69), and very high shrubs values (.88) are highly associated with high clay values (1.0) (Figure 3.9). In terms of the original data, it can be seen in 11E, where it has a high forbs count (32.2), high shrubs counts (3.5) and high clay content in the A horizon (7.5%).

Fourth Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Vcs, Cs, and Ms. The canonical correlation of the first variates was .90 (Table 3.11) (Prob>Chi-SQ = .0591) which can be interpreted as high Bgr values (.87) and moderately high Asc values (.45) are highly associated with moderately high Vcs values (.58), and very low Ms values (-.95) (Figure 3.10). No specific trend is noticed in terms of the original data.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was .96 (Table 3.12) (Prob>Chi-SQ = .0023). This can be interpreted as high Etr values (.65), moderately high Pst values (.42), very low Par values (-.89), and moderately low Pvi values (-.43) are highly associated with high Ms values (.93) and moderately low Vcs values (-.56) (Figure 3.11). In terms of the original data, an increase in Ms percentages is accompanied by an increase in Etr counts, while an increase in Vcs percentages

TABLE 3.10

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, THIRD GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.46191054	1.11900646	0.83785499	13.44029	9	0.1429
2	0.59738697	0.72551717	0.55645458	3.14964	4	0.5355
3	-0.21638312	1.99199449	0.00078409	0.00001	1	0.9466

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.690105	0.689420	0.878130
VAR # 2	-0.254375	0.452756	-0.150164
VAR # 3	-0.657569	-0.565431	0.454245

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	0.238712	-0.059664	0.950575
VAR # 2	-0.780526	0.733770	0.133777
VAR # 3	0.577751	0.676774	0.029414

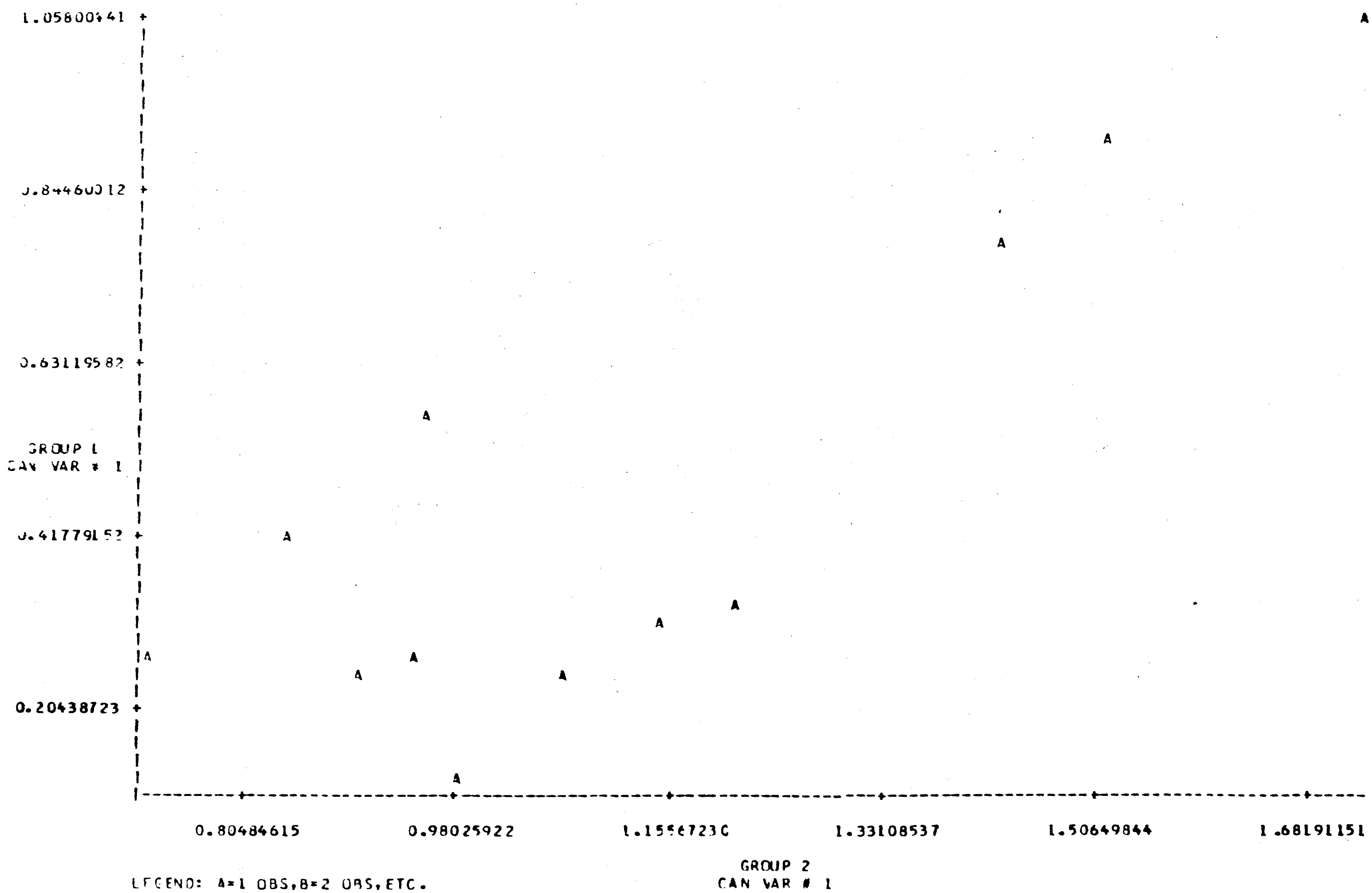


Figure 3.9. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Third Group, Third Set of Variables.

TABLE 3.11

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, FOURTH GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.01452221	-1.28482645	0.85596904	20.43354	12	0.0591
2	0.34713135	1.24943270	0.72534921	7.15004	6	0.3067
3	0.94769474	-1.06295380	0.37072518	1.18278	2	0.5590

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	-0.275375	0.873363	0.452672	0.012648
VAR # 2	-0.180363	-0.408372	0.852638	0.035681
VAR # 3	0.993665	0.215425	-0.177365	-0.343169

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	0.580326	-0.139094	-0.952316
VAR # 2	0.583770	0.824642	0.203784
VAR # 3	-0.567833	0.548287	-0.227081

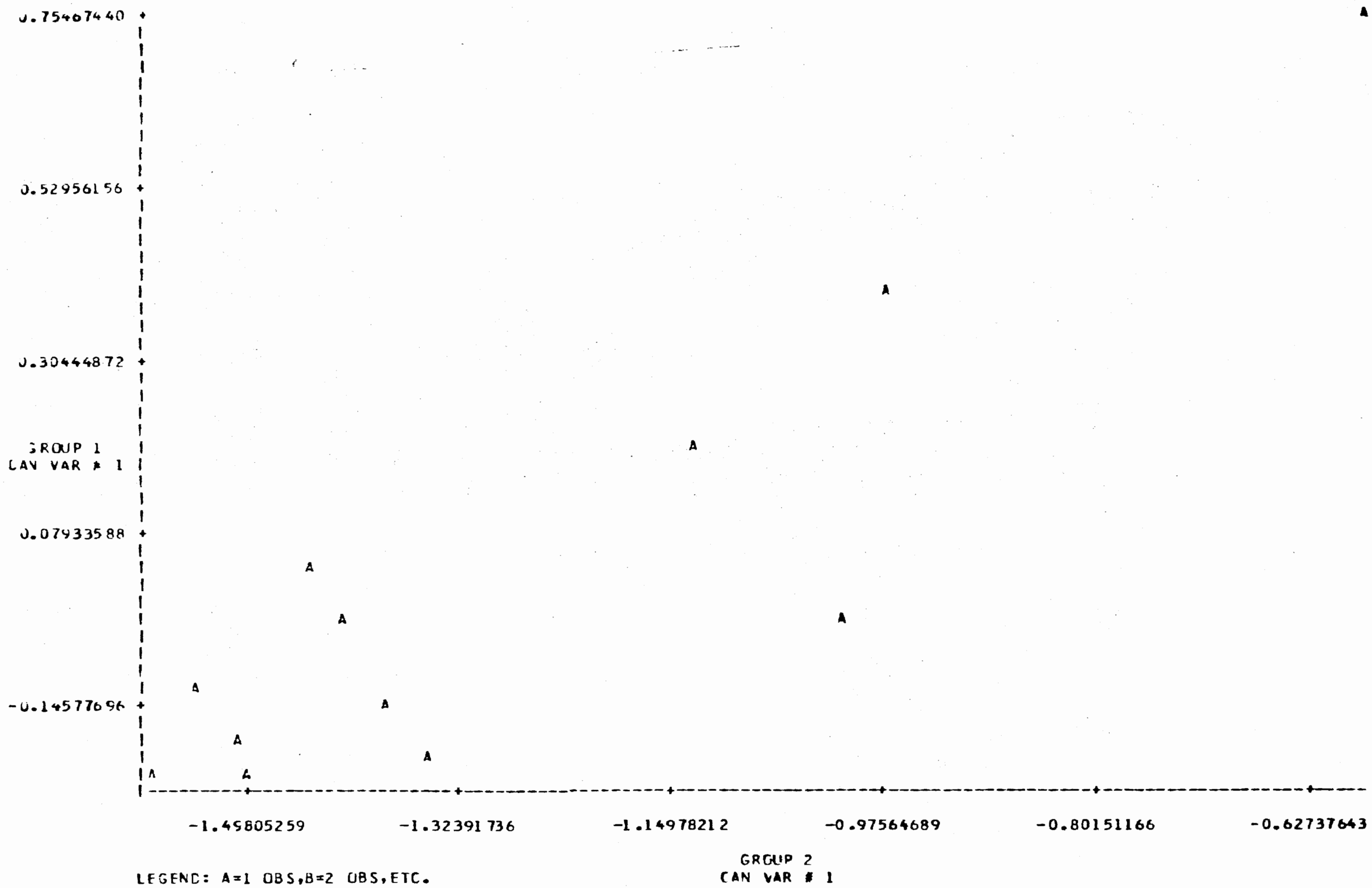


Figure 3.10. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Fourth Group, First Set of Variables.

TABLE 3.12

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, FOURTH GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.08881298	1.29457859	0.96408456	30.60459	12	0.0023
2	0.32916194	0.74015255	0.77547811	9.39210	6	0.1516
3	0.62409053	-1.45496960	0.47385745	2.03440	2	0.3630

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	-0.426653	0.647085	0.422805	-0.891151
VAR # 2	0.803094	0.681624	-0.216241	0.353769
VAR # 3	-0.073453	0.135363	0.713698	0.232718

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	-0.556204	0.355467	0.926689
VAR # 2	0.560462	0.874234	-0.033888
VAR # 3	-0.613613	0.330692	-0.374297

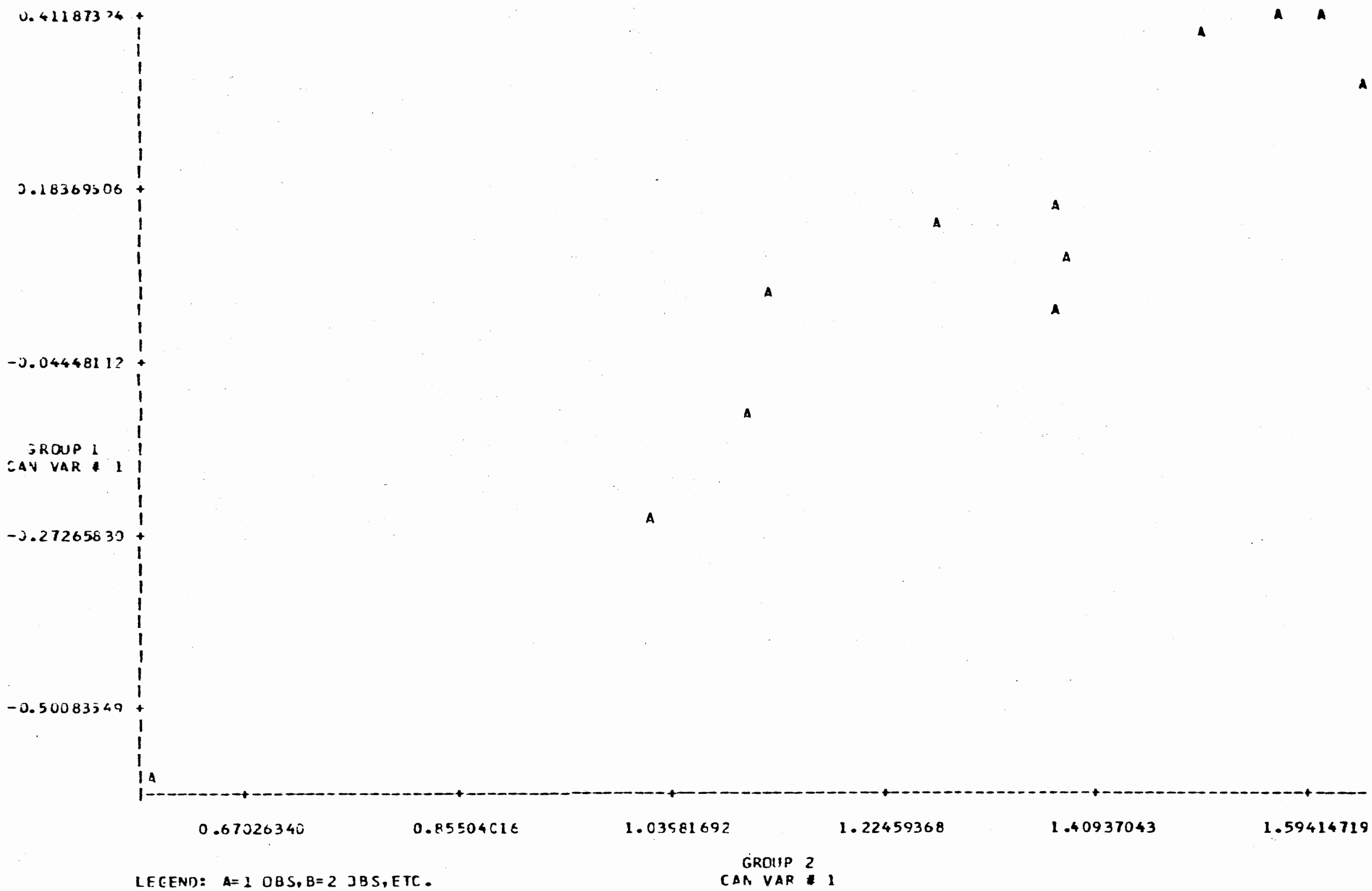


Figure 3.11. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Fourth Group, Second Set of Variables.

is accompanied by an increase in Par and Pvi counts.

The Third Set of Variables. Other grasses, forbs, and shrubs with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was .58 (Table 3.13) (Prob>Chi-SQ = .8018). This can be interpreted as very high other grasses values (.97), very high forbs values (.74), and high shrubs values (.53) are moderately associated with high Vcs values (.53) and high Ms values (.46) (Figure 3.12). This can be interpreted, in terms of the original data, as high counts of other grasses, forbs, and shrubs are corresponding to high Vcs and Ms percentages.

Fifth Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Fs and Vfs. The canonical correlation of the first variates of this set was .95 (Table 3.14) (Prob>Chi-SQ = .0046). This can be interpreted as high Bgr values (.82) and very low Scr values (-.56) are highly associated with very high Vfs values (1.0) and high Fs values (.70) (Figure 3.13). In terms of the original data, a high Bgr count corresponds to high percentages of Vfs.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Fs and Vfs. The canonical correlation of the first variates of this set was .92 (Table 3.15) (Prob>Chi-SQ = .0079). This can be interpreted as high Etr values (.67), high Pst values (.63), and very low Par values (-.78) are highly associated with very low Fs values (-.85) and very low Vfs values (-.97) (Figure 3.14). In terms of the original data, a high count of Par corresponds to high percentages of Fs and Vfs.

TABLE 3.13

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, FOURTH GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.33666816	1.53069399	0.58043316	5.37315	9	0.8018
2	0.55279635	-1.20608409	0.44193968	1.88106	4	0.7604
3	0.46866784	0.73761028	0.06320331	0.03402	1	0.8321

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.973408	0.737675	0.531165
VAR # 2	0.132814	0.604448	-0.517533
VAR # 3	-0.166649	0.300306	0.670838

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	0.532712	-0.337907	0.458841
VAR # 2	0.571076	-0.433907	-0.885808
VAR # 3	0.62457[illegible]	0.332574	-0.069348

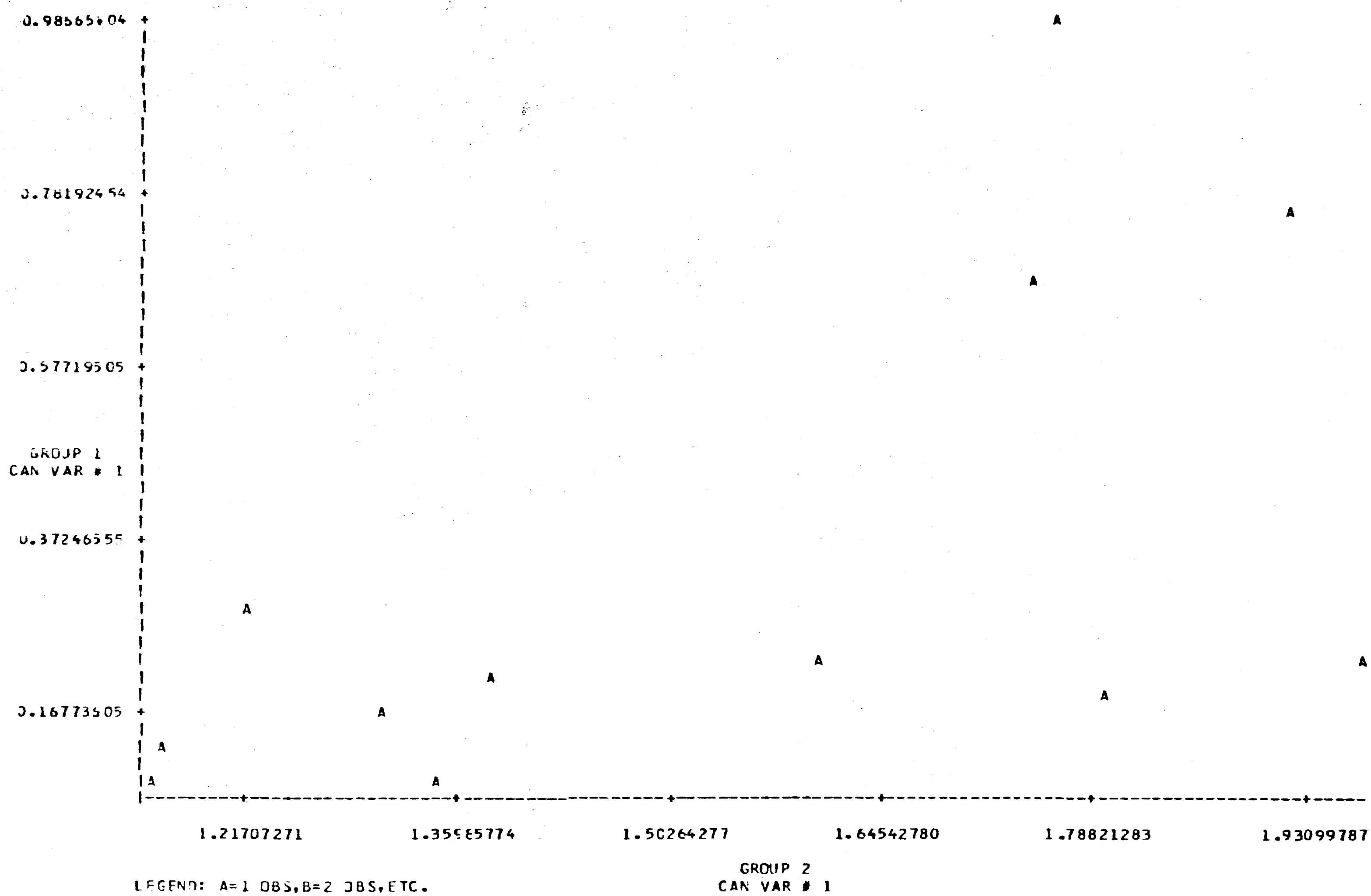


Figure 3.12. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Fourth Group, Third Set of Variables.

TABLE 3.14

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, FIFTH GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.31699054	1.46289840	0.95495907	22.27068	8	0.0046
2	0.20459525	0.17578550	0.41624614	1.61726	3	0.6597

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	-0.557851	0.821501	0.134981	0.399073
VAR # 2	0.502926	0.439857	0.093252	-0.790041

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	0.690976	0.999843
VAR # 2	0.722878	0.017710

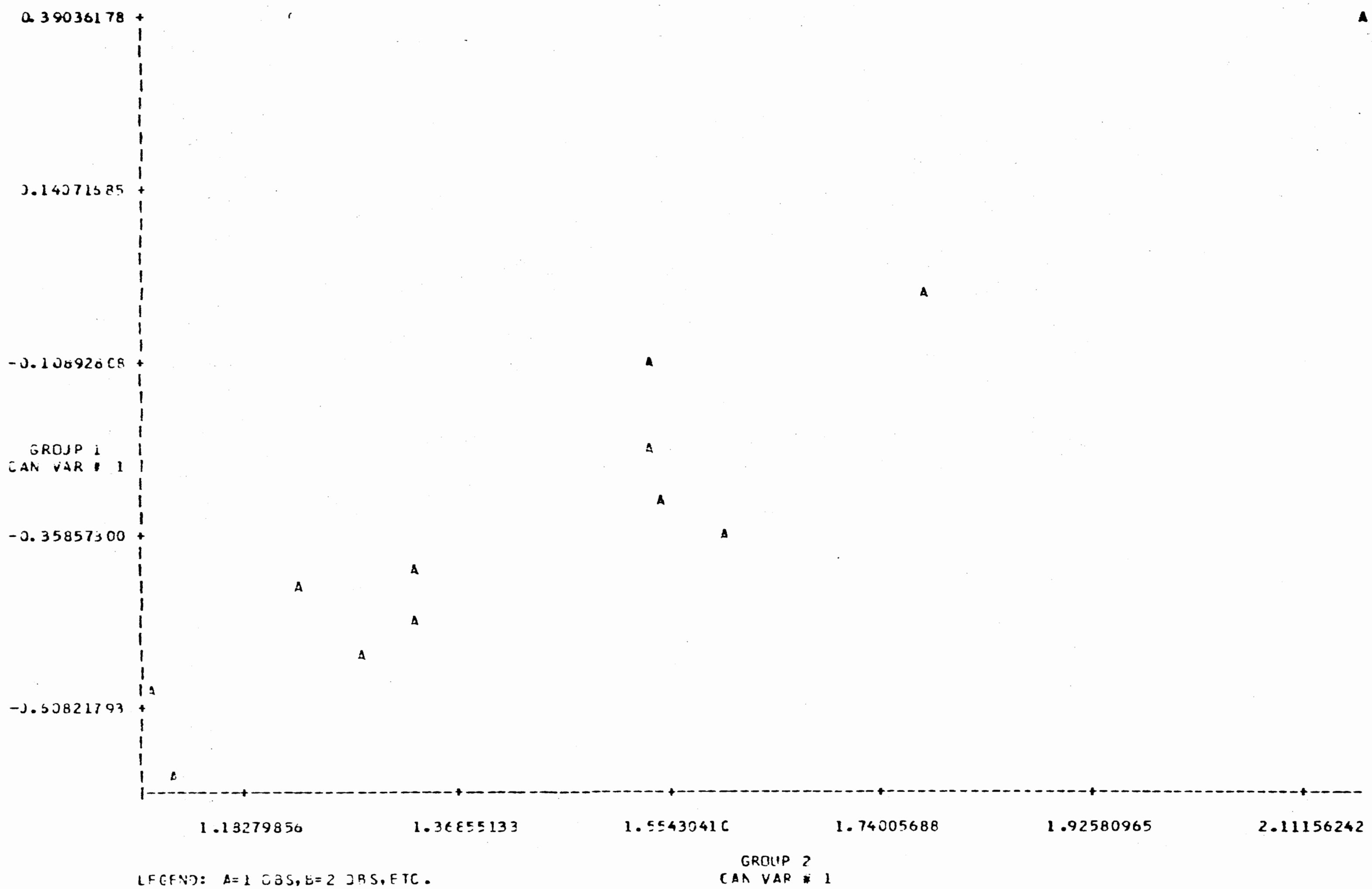


Figure 3.13. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Fifth Group, First Set of Variables.

TABLE 3.15

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, FIFTH GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.27312280	-1.45547357	0.91906810	20.78280	8	0.0079
2	0.09782345	-0.20226017	0.66454994	4.95318	3	0.1735

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	-0.266483	0.673901	0.627156	-0.782858
VAR # 2	-0.179599	-0.642966	0.722346	-0.077922

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	-0.852178	-0.971437
VAR # 2	0.523252	-0.237299

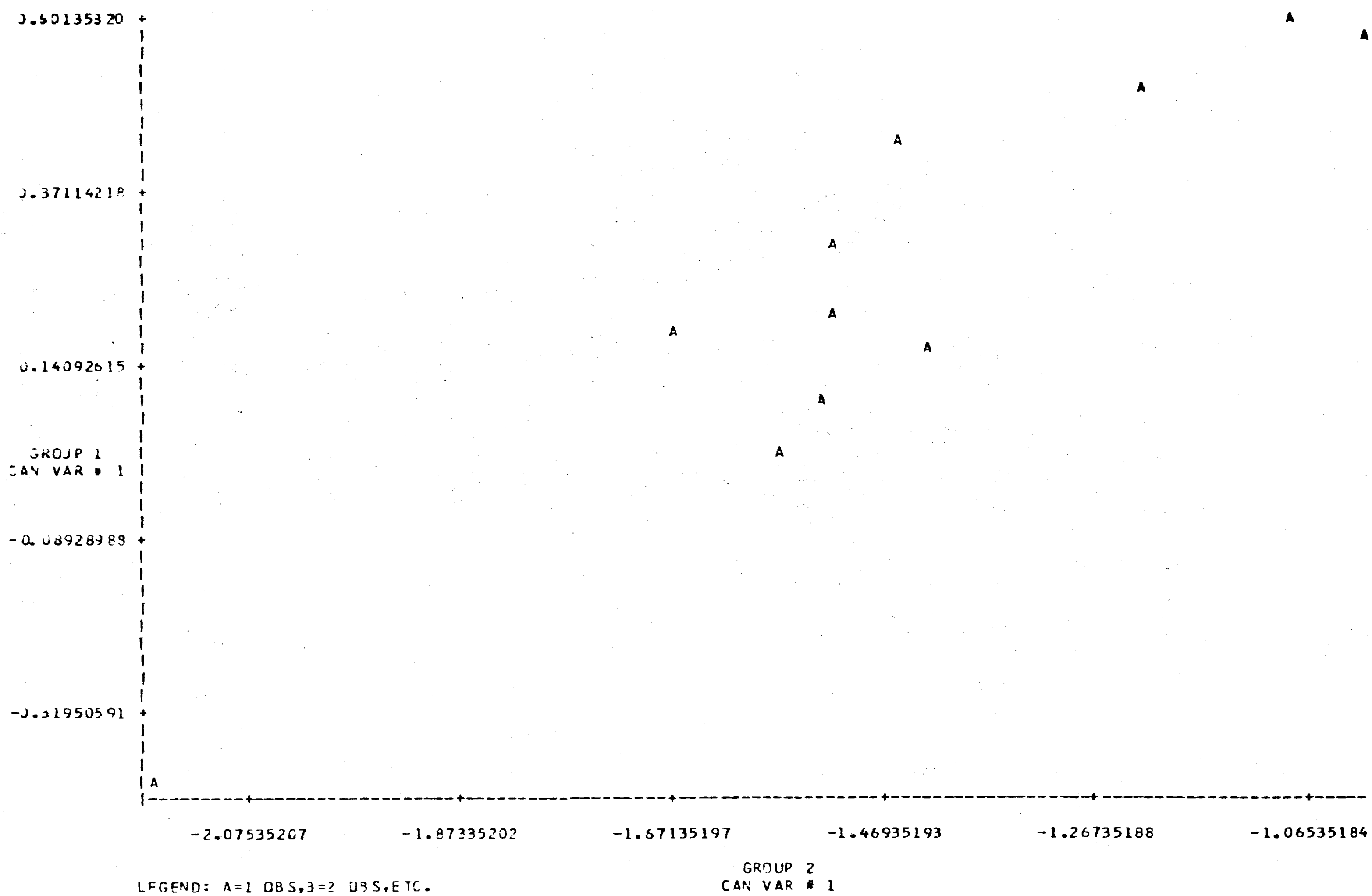


Figure 3.14. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Fifth Group, Second Set of Variables.

The Third Set of Variables. Other grasses, forbs, and shrubs with Fs and Vfs. The canonical correlation of the first variates of this set was .49 (Table 3.16) (Prob>Chi-SQ = .8440). This can be interpreted as very high forbs values (.69) is moderately low associated with very high Fs values (1.0) and high Vfs values (.65) (Figure 3.15). In terms of the original data, a high count of forbs is associated with high percentages of Fs and Vfs.

B Horizons

First Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with thickness, pH, and OM. The canonical correlation of the first variates was .96 (Table 3.17) (Prob>Chi-SQ = .0040). This can be interpreted as low Scr values (-.31), low Bgr values (-.37), and high Asc values (.89) are highly associated with high thickness values (.84), low pH values (-.60), and low OM values (-.02) (Figure 3.16). In terms of the original data, it can be interpreted as high counts of Scr and Bgr and low counts of Asc are highly associated with low thickness of the A horizon, high pH values, and high organic matter content.

The Second Set of Variables. Pvi, Etr, Pst, and Par with thickness, pH, and OM. The canonical correlation of the first variates of this set was .82 (Table 3.18) (Prob>Chi-SQ = .0526). This can be explained as high Etr values (.77), low Pvi values (-.46), and low Par values (-.44) are highly associated with low thickness values (-.70) and low pH values (-.63) (Figure 3.17). In terms of the original data, an increase in the thickness of the horizon, higher pH values are

TABLE 3.16

CANONICAL CORRELATION ANALYSIS FOR A HORIZONS, FIFTH GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.65343128	1.06925879	0.48584032	2.72243	6	0.8440
2	0.376[illegible]0420	-1.[illegible]1373463	0.18084492	0.29925	2	0.8585

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.[illegible]2533	0.685904	-0.290368
VAR # 2	0.[illegible]6292	0.314516	0.910399

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	0.[illegible]7524	0.651963
VAR # 2	-0.[illegible]70321	-0.758251

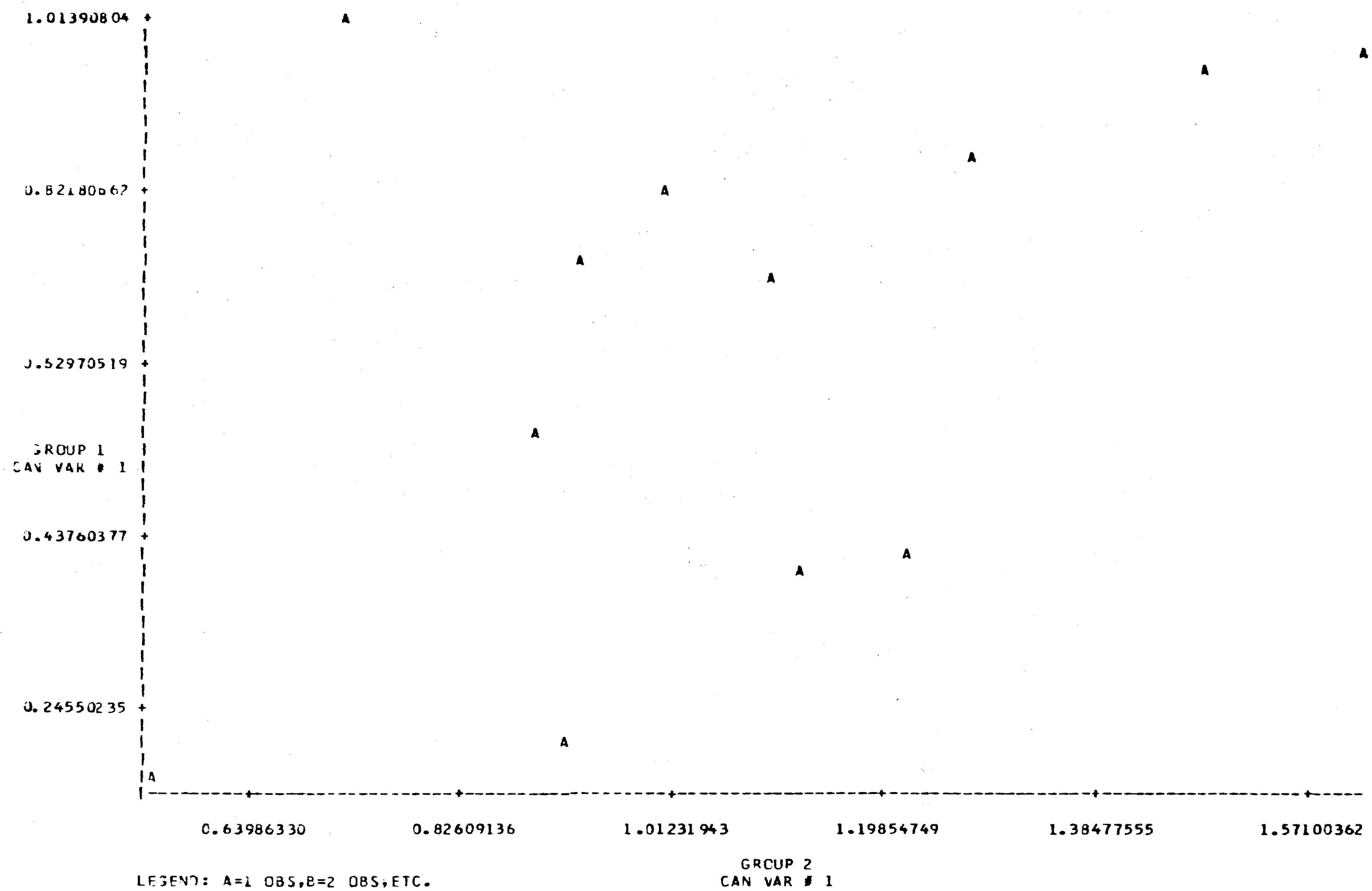


Figure 3.15. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for A Horizons, Fifth Group, Third Set of Variables.

TABLE 3.17

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, FIRST GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.19724620	-4.03128005	0.96391839	29.03784	12	0.0040
2	0.81383650	-6.66102339	0.75716953	7.86159	6	0.2475
3	-0.07976308	-3.33842899	0.35041771	1.04809	2	0.5979

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	-0.306242	-0.370813	0.892443	0.043362
VAR # 2	0.966824	-0.366806	-0.267533	-0.303815
VAR # 3	-0.388759	-0.562892	-0.078086	0.735882

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICKI	PH	OM
VAR # 1	0.840645	-0.599408	-0.017884
VAR # 2	-0.521570	-0.800439	0.391476
VAR # 3	-0.145878	-0.002573	-0.920014

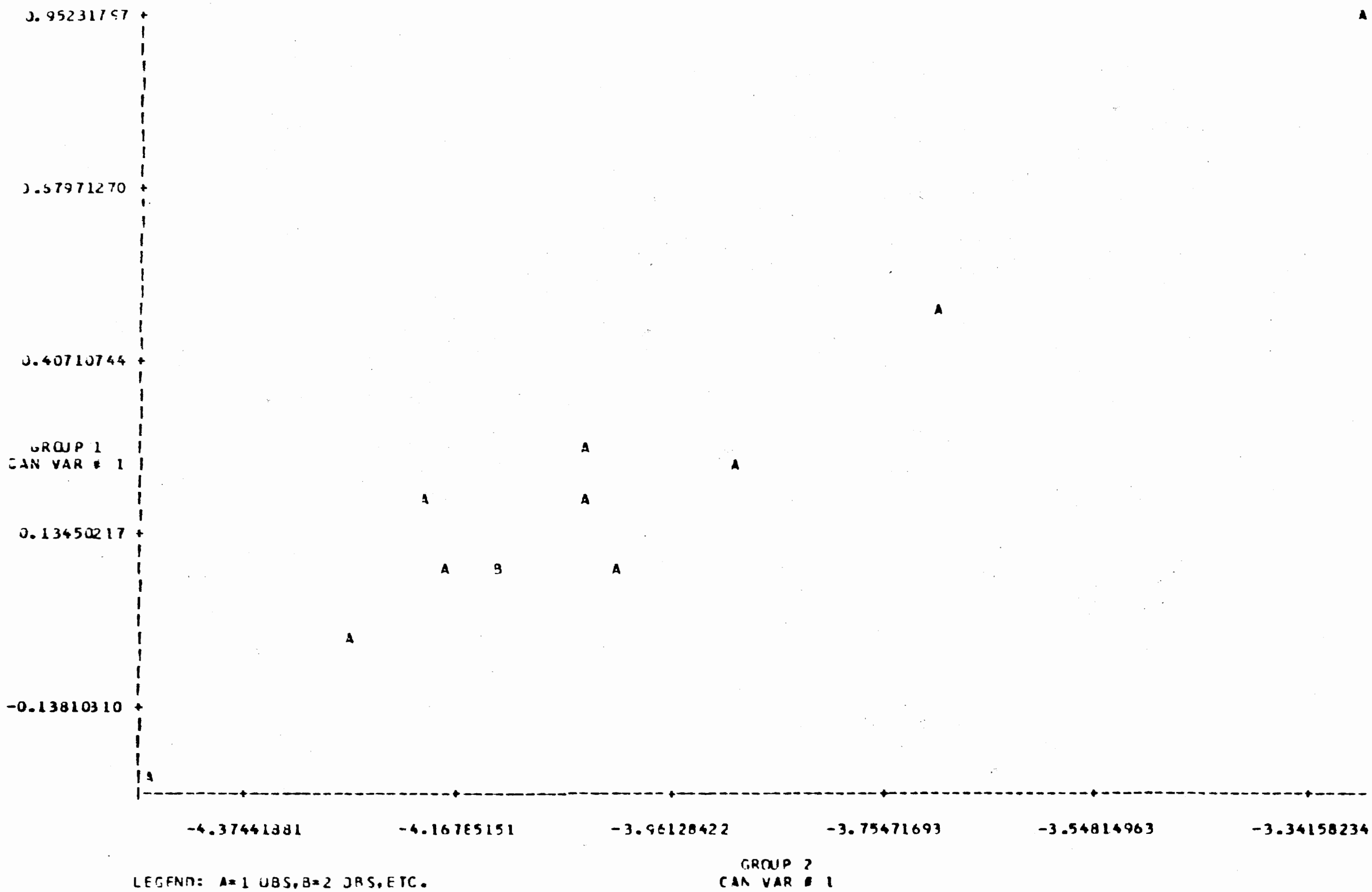


Figure 3.16. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, First Group, First Set of Variables.

TABLE 3.18

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, FIRST GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.35383454	-5.22778390	0.82093853	20.83704	12	0.0526
2	0.27464564	-5.65552064	0.79267360	11.87164	6	0.0643
3	0.37525133	3.52216708	0.62445388	3.95362	2	0.1360

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	-0.463776	0.771623	0.345477	-0.444838
VAR # 2	0.712298	0.509811	0.255441	-0.113265
VAR # 3	0.521206	0.197153	-0.291290	0.884719

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	OM
VAR # 1	-0.698648	-0.628293	0.447828
VAR # 2	0.680846	-0.777718	0.047320
VAR # 3	0.219227	0.020051	0.892866

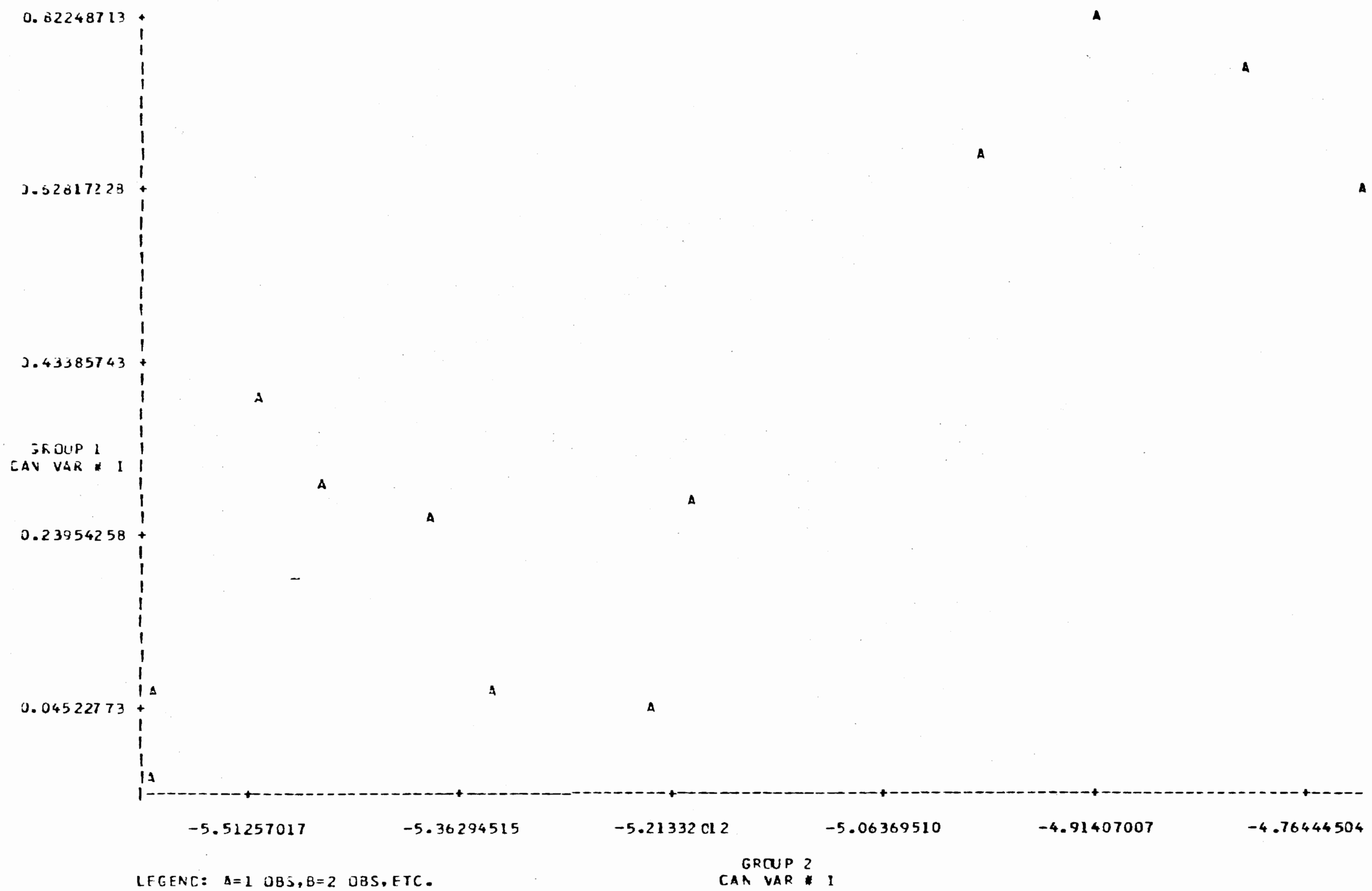


Figure 3.17. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, First Group, Second Set of Variables.

accompanied with high counts of Etr and Pvi.

The Third Set of Variables. Other grasses, forbs, and shrubs with thickness, pH, and OM. The canonical correlation of the first variates of this set was .74 (Table 3.19) (Prob>Chi-SQ =.4165). This can be interpreted as high shrubs values (.82) and moderately low other grasses values (-.28) are highly associated with moderately low thickness values (-.44) and low pH values (-.75) (Figure 3.18). In terms of the original data, the thickness of the B horizon seems highly correlated with high counts of other grasses more than forbs and shrubs.

Second Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Ca, Mg, and K. The canonical correlation of the first variates of this set was .84 (Table 3.20) (Prob>Chi-SQ = .3246). This can be explained as high Bgr values (.81), high Asc values (.60), and moderately low Scr values (-.29) are highly associated with high K values (.87), high Mg values (.76), and moderately high Ca values (.52) (Figure 3.19). In terms of the original data, higher values for Ca, Mg, and K corresponds with higher Bgr and Asc counts.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Ca, Mg, and K. The canonical correlation of the first variates of this set was .76 (Table 3.21) (Prob>Chi-SQ = .6850). This can be interpreted as high Pvi values (.71), high Par values (.66), and very low Pst values (-.75) are highly associated with very high K values (.98), moderately high Mg values (.51), and moderately high Ca values (.56) (Figure 3.20). No specific trend was noticed in terms of the original data.

TABLE 3.19

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, FIRST GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.07153494	-7.78595680	0.73544767	9.23030	9	0.4165
2	0.06452858	-0.07432686	0.51157840	2.61346	4	0.5276
3	0.77956271	-3.32815382	0.06353189	0.03438	1	0.8315

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	-0.281157	-0.129233	0.815702
VAR # 2	0.893191	0.441808	0.556528
VAR # 3	0.350910	0.687752	0.157820

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	OM
VAR # 1	-0.443175	-0.750794	-0.115928
VAR # 2	0.254096	0.315432	-0.984405
VAR # 3	0.855669	-0.580354	0.132319

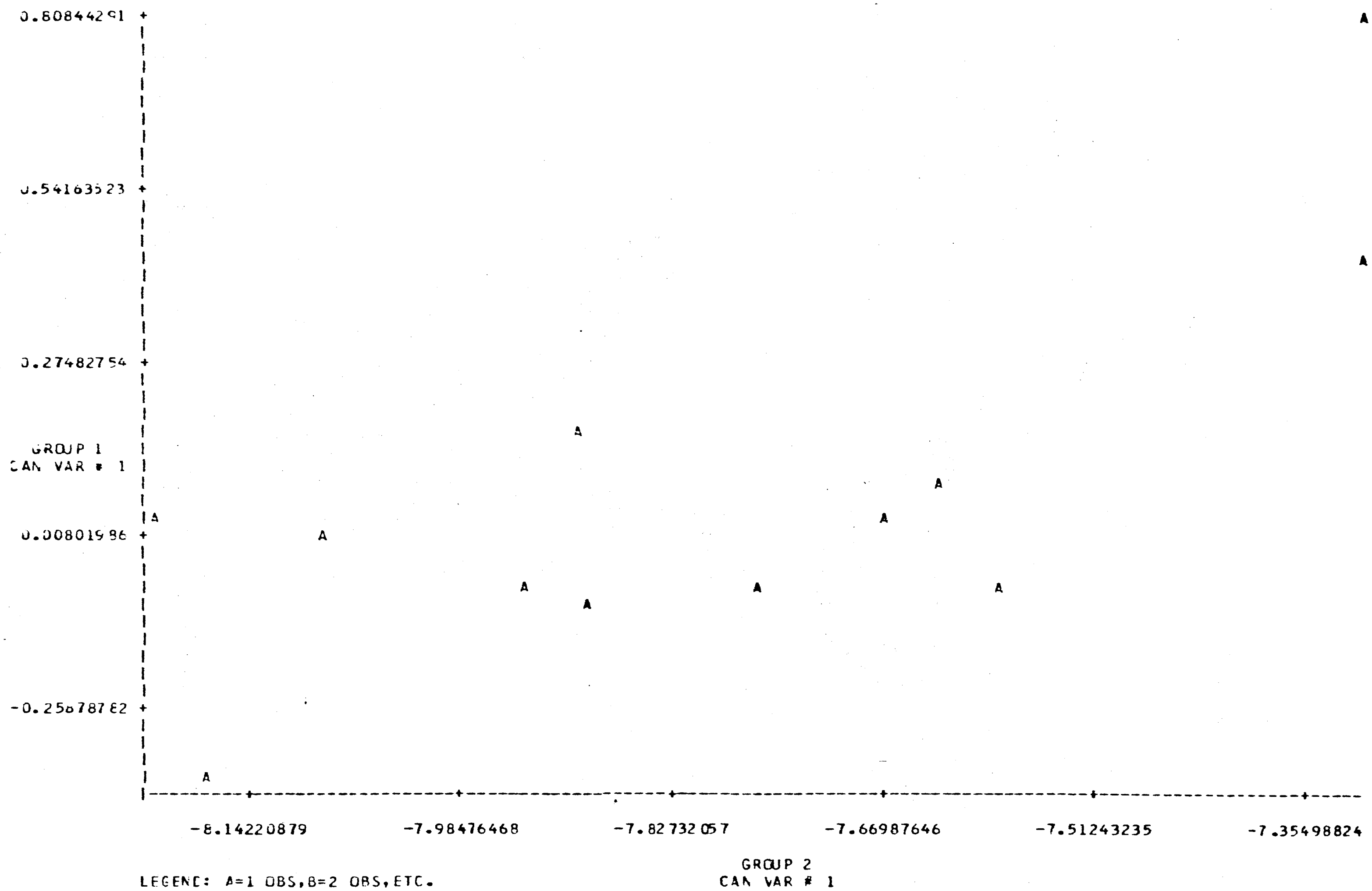


Figure 3.18. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, First Group, Third Set of Variables.

TABLE 3.20

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, SECOND GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.15784955	1.94019940	0.83914200	13.63069	12	0.3246
2	0.16053789	0.57038961	0.61180709	3.88722	6	0.6941
3	1.08922509	0.59405688	0.12985237	0.13604	2	0.9254

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	-0.285072	0.812553	0.592613	0.077308
VAR # 2	-0.529241	0.065440	0.153362	0.591586
VAR # 3	0.620488	-0.076450	0.219588	-0.000487

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	0.524391	0.759355	0.870014
VAR # 2	-0.107868	-0.574328	0.491287
VAR # 3	-0.844618	-0.305824	0.041379

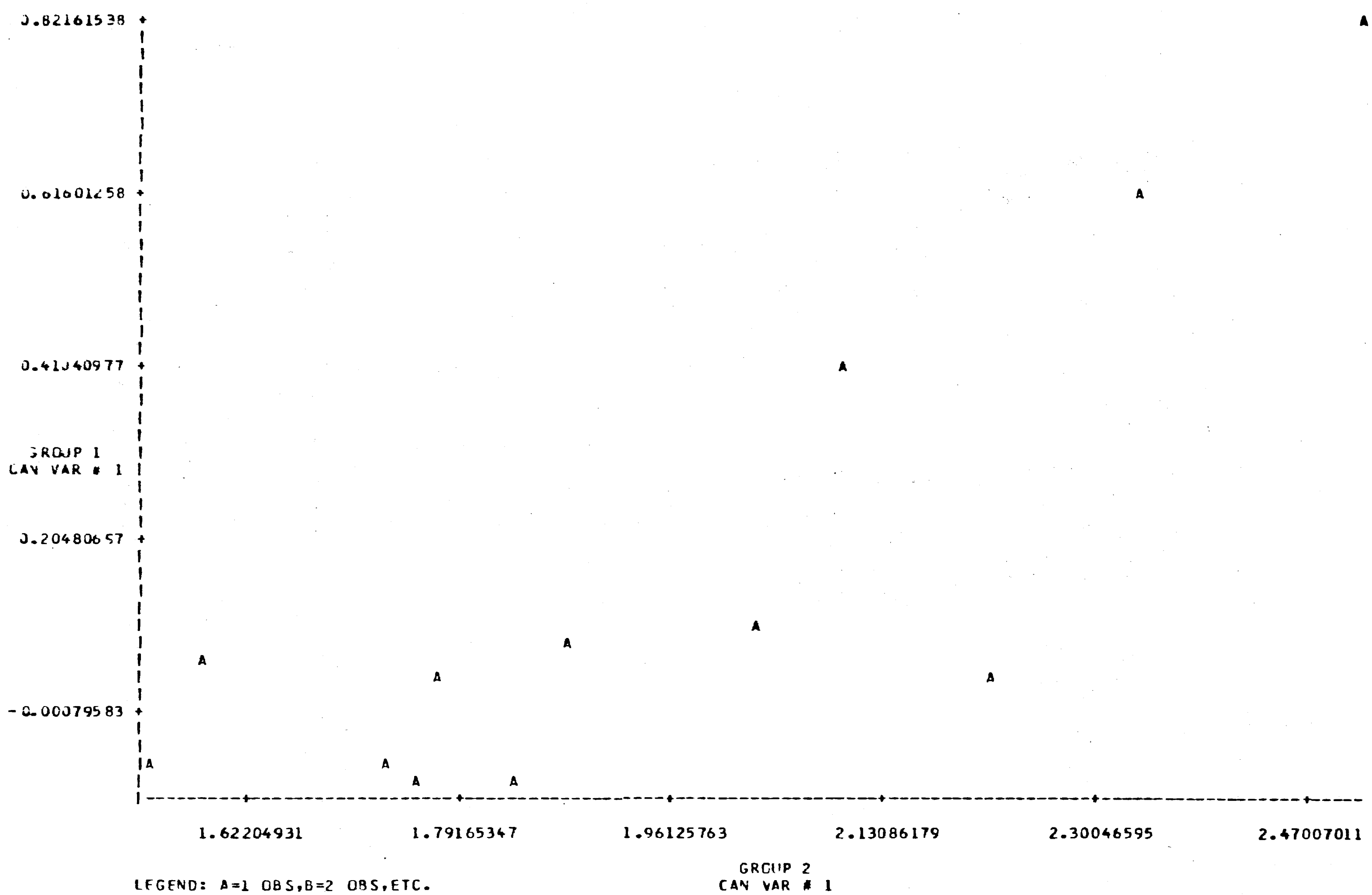


Figure 3.19. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Second Group, First Set of Variables.

TABLE 3.21

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, SECOND GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.26194543	1.90118897	0.76244881	9.22096	12	0.6850
2	0.28657156	-0.02978107	0.48791085	2.25561	6	0.8950
3	0.55442479	-0.90951370	0.10008839	0.08055	2	0.9493

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.713743	-0.268942	-0.753856	0.655046
VAR # 2	0.462212	-0.318853	0.651790	0.148409
VAR # 3	0.507371	0.827444	0.082391	0.276689

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	0.553021	0.512956	0.976450
VAR # 2	0.515554	0.358270	-0.160004
VAR # 3	0.650243	-0.015795	-0.144722

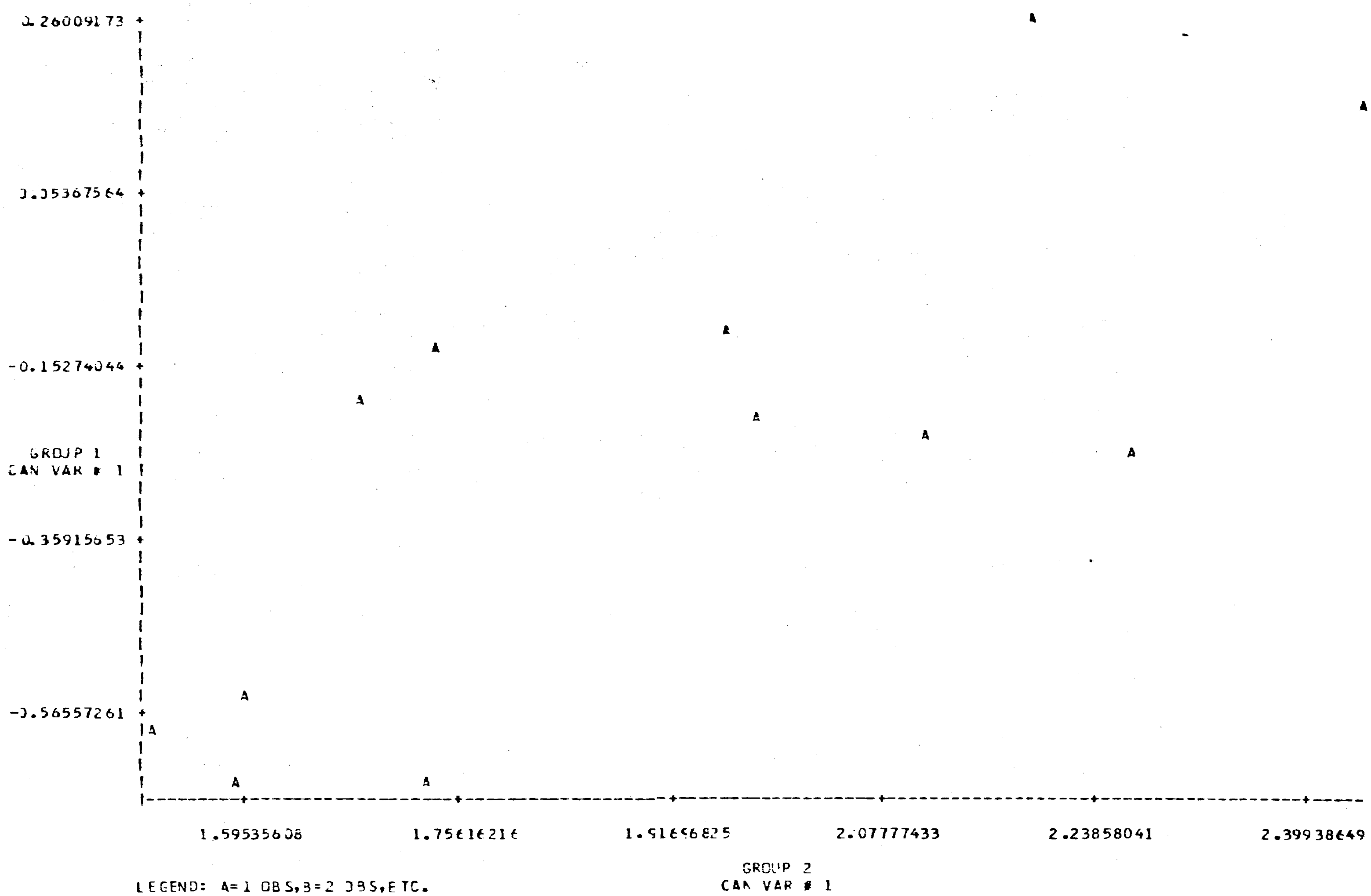


Figure 3.20. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Second Group, Second Set of Variables.

The Third Set of Variables. Other grasses, forbs, and shrubs with Ca, Mg, and K. The canonical correlation of the first variates of this set was .55 (Table 3.22) (Prob>Chi-SQ = .8988). This can be interpreted as very high forbs values (.79) are moderately associated with very high Ca values (.64) and very high K values (.82) (Figure 3.21). No specific trend was noticed in terms of the original data.

Third Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Na, CEC, and Clay. The canonical correlation of the first variates of this set was .89 (Table 3.23) (Prob>Chi-SQ = .2695). This can be explained as high Bgr values (.80), high Asc values (.60), and moderately low Scr values (0.46) are highly associated with high CEC values (.99) and high Clay values (.85) (Figure 3.22). In terms of the original data, high counts of Bgr and Asc are favored by high values of CEC and Clay percent.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Na, CEC, and Clay. The canonical correlation of the first variates of this set was .94 (Table 3.24) (Prob>Chi-SQ = .0247). This can be interpreted as high Par values (.92), high Pvi values (.82), and moderately low Pst values (-.40) are highly associated with high Clay values (.84) and high CEC values (.80) (Figure 3.23). In terms of the original data, an increase in Par and Pvi counts is favored by high values of Clay and CEC.

The Third Set of Variables. Other grasses, forbs, and shrubs with Na, CEC, and Clay. The canonical correlation of the first variates of this set was .78 (Table 3.25) (Prob>Chi-SQ = .2554). This can be explained as very high other grasses values (.88) and very high forbs

TABLE 3.22

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS,
SECOND GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.72583987	1.24546688	0.54647970	4.18943	9	0.8988
2	0.29400625	-0.45658883	0.35465543	1.17419	4	0.8824
3	-0.06142799	-1.63492531	0.06090213	0.03159	1	0.8363

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.199928	0.785522	-0.100198
VAR # 2	0.706043	0.542253	0.898076
VAR # 3	0.679361	0.298190	-0.428276

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	0.643745	0.228114	0.818923
VAR # 2	0.765240	0.747360	-0.207300
VAR # 3	0.000485	-0.624033	-0.535156

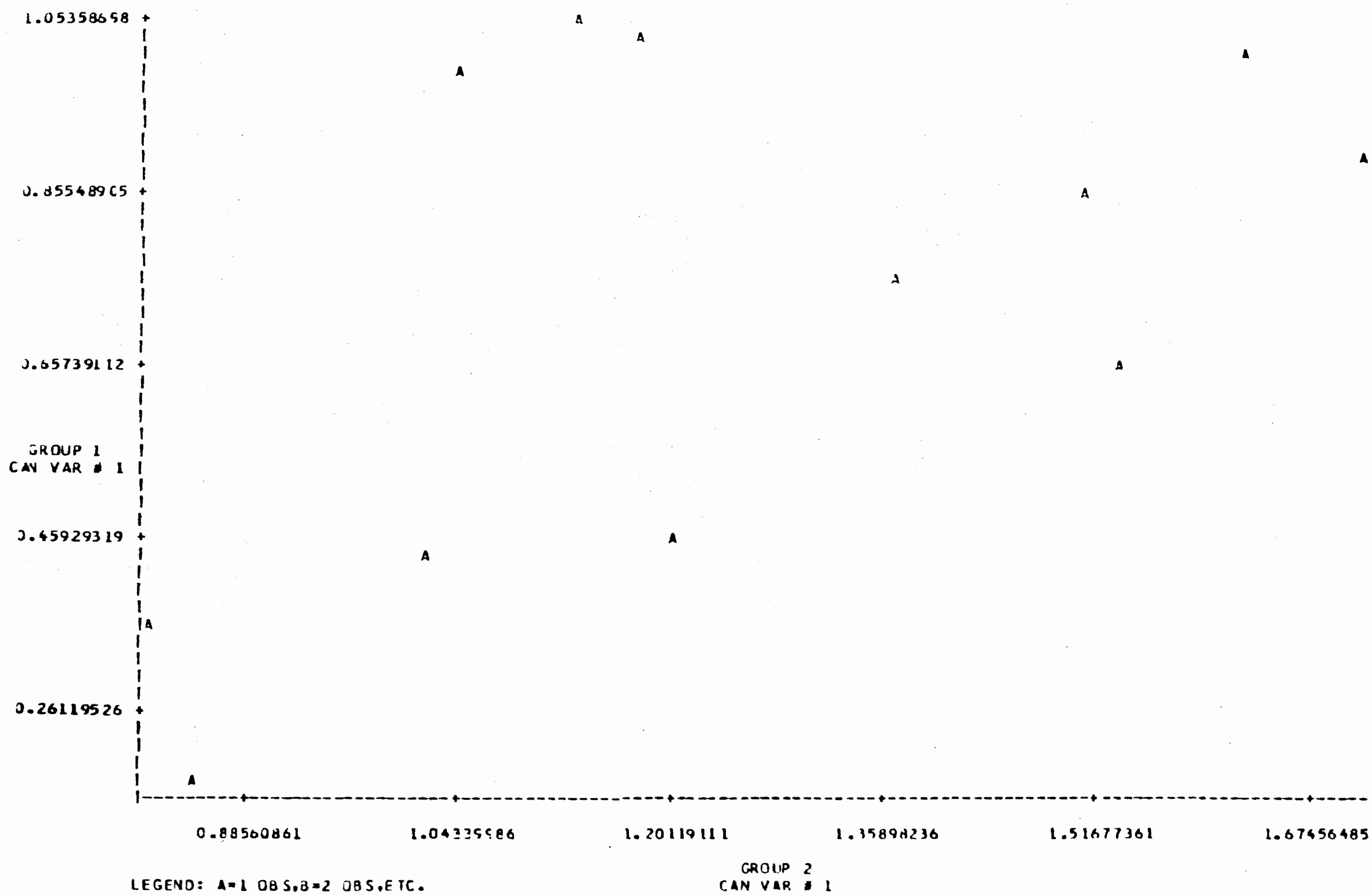


Figure 3.21. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Second Group, Third Set of Variables.

TABLE 3.23

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, THIRD GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.03423720	1.17079349	0.85337213	14.49845	12	0.2695
2	0.61928181	-0.62357486	0.37940394	1.69804	6	0.9443
3	0.42434399	-0.32194097	0.23504689	0.45465	2	0.7983

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	-0.459323	0.800156	0.595338	0.240905
VAR # 2	0.858566	0.490885	-0.432286	-0.479596
VAR # 3	-0.116219	0.169481	-0.169682	0.837375

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	-0.084117	0.987252	0.854176
VAR # 2	-0.738083	-0.126686	0.271548
VAR # 3	-0.669446	0.096355	-0.443448

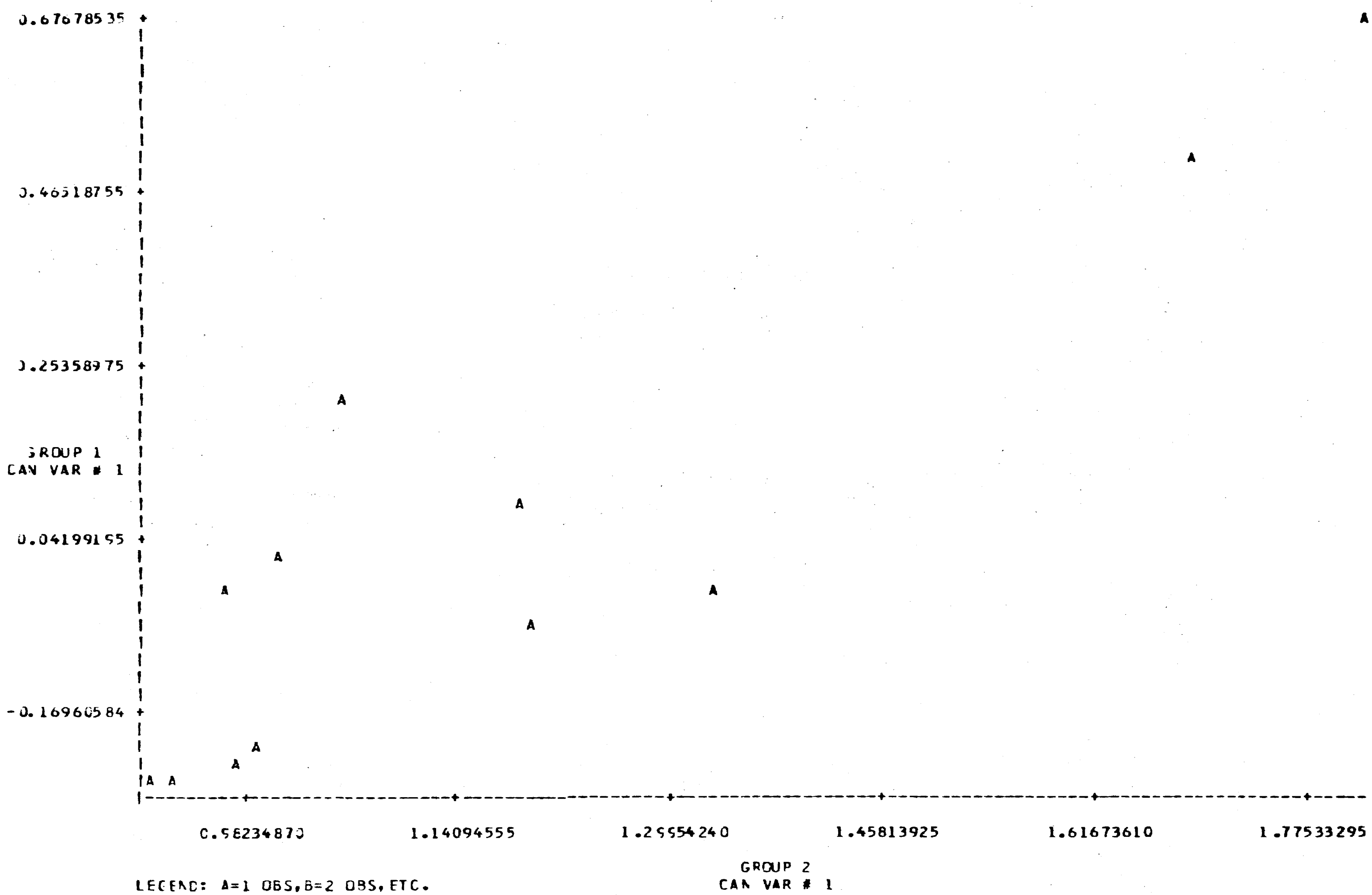


Figure 3.22. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Third Group, First Set of Variables.

TABLE 3.24

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, THIRD GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.24773005	1.29277833	0.93935703	23.38189	12	0.0247
2	0.57004705	-0.34223555	0.71490381	6.25873	6	0.3951
3	0.25468896	0.27345851	0.25414380	0.53415	2	0.7687

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.921409	0.028467	-0.370372	0.922745
VAR # 2	-0.261671	0.583141	0.452145	0.013321
VAR # 3	0.161159	-0.428630	0.783978	0.056597

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	0.479181	0.790994	0.843848
VAR # 2	0.619726	-0.604565	-0.080767
VAR # 3	0.621551	-0.093973	-0.530469

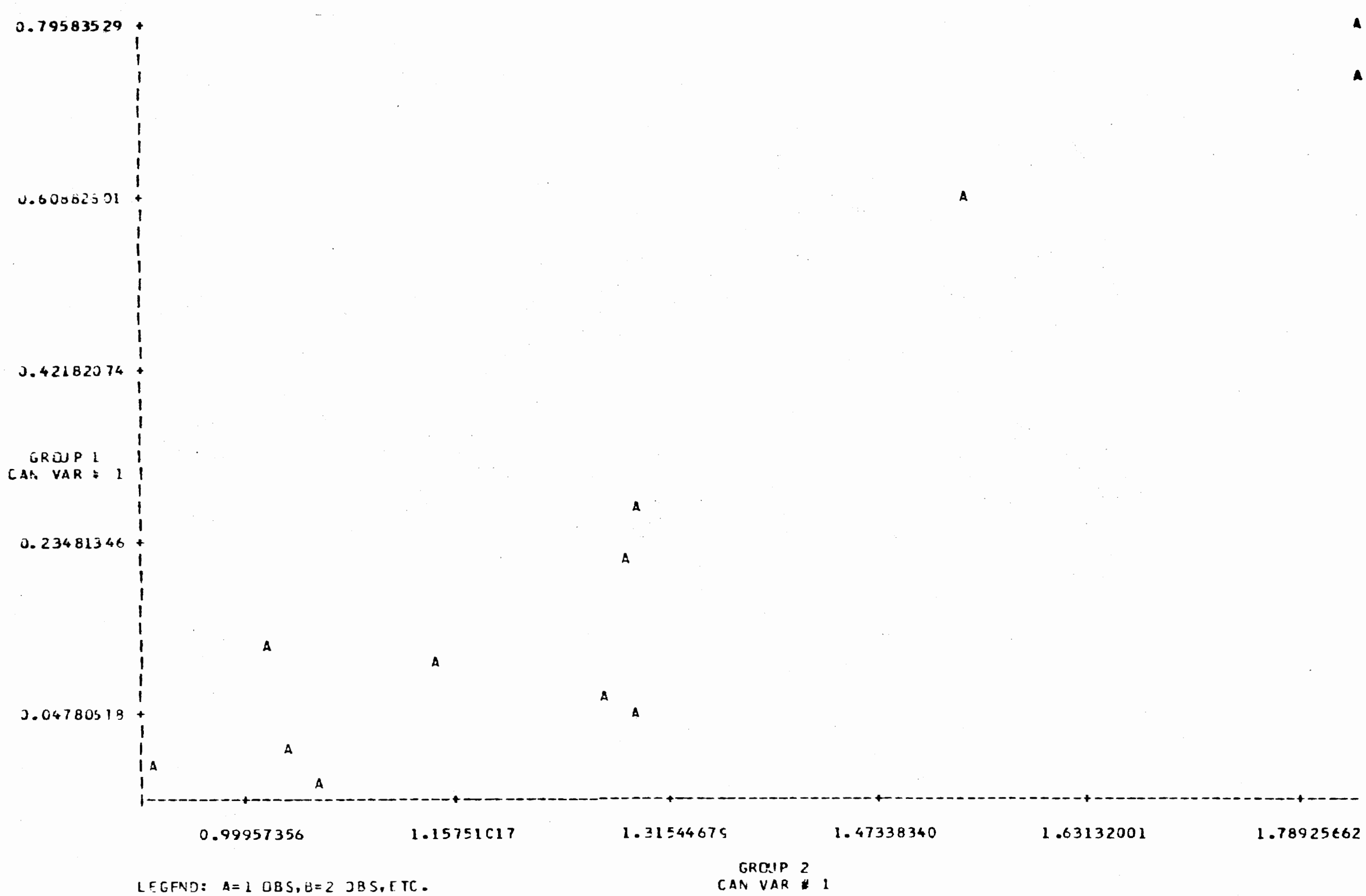


Figure 3.23. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Third Group, Second Set of Variables.

TABLE 3.25

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS,
THIRD GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.55394211	-0.18317307	0.77752425	11.29447	9	0.2554
2	0.54932233	0.06076575	0.48175086	3.40889	4	0.4938
3	-0.09192229	-1.35129721	0.35777744	1.16426	1	0.2804

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.684978	0.533214	0.106467
VAR # 2	-0.761909	0.358295	0.438160
VAR # 3	0.384991	0.027137	0.892570

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	-0.645678	0.198126	-0.365121
VAR # 2	-0.664631	0.387538	0.675567
VAR # 3	-0.369032	-0.900311	-0.640544

values (.93) are highly associated with moderately high CEC values (.20) (Figure 3.24). In terms of the original data, high counts of other grasses and forbs are favored by moderate values of CEC.

Fourth Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was .87 (Table 3.26) (Prob>Chi-SQ = .2111). This can be interpreted as high Bgr values (.71) and moderately low Aha values (-.55) are highly associated with very low Ms values (-.87) and moderately low Cs values (-.67) (Figure 3.25). In terms of the original data, the higher percentages of Ms and Cs, the higher the Aha counts.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was .76 (Table 3.27) (Prob>Chi-SQ = .7975). This can be explained as very high Etr values (.89) and moderately low Par values (-.59) are highly associated with high Ms values (.91) and moderately high Cs values (.67) (Figure 3.26). In terms of the original data, higher counts of Etr are associated with higher percentages of Cs and Ms.

The Third Set of Variables. Other grasses, forbs, and shrubs with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was .80 (Table 3.28) (Prob>Chi-SQ = .4187). This can be explained as high shrubs values (.65) and moderately low forbs values (-.41) are highly associated with high Ms values (.60) and very low Vcs values (-.63) (Figure 3.27). In terms of the original data, high shrubs counts are associated with high percentages of Ms.

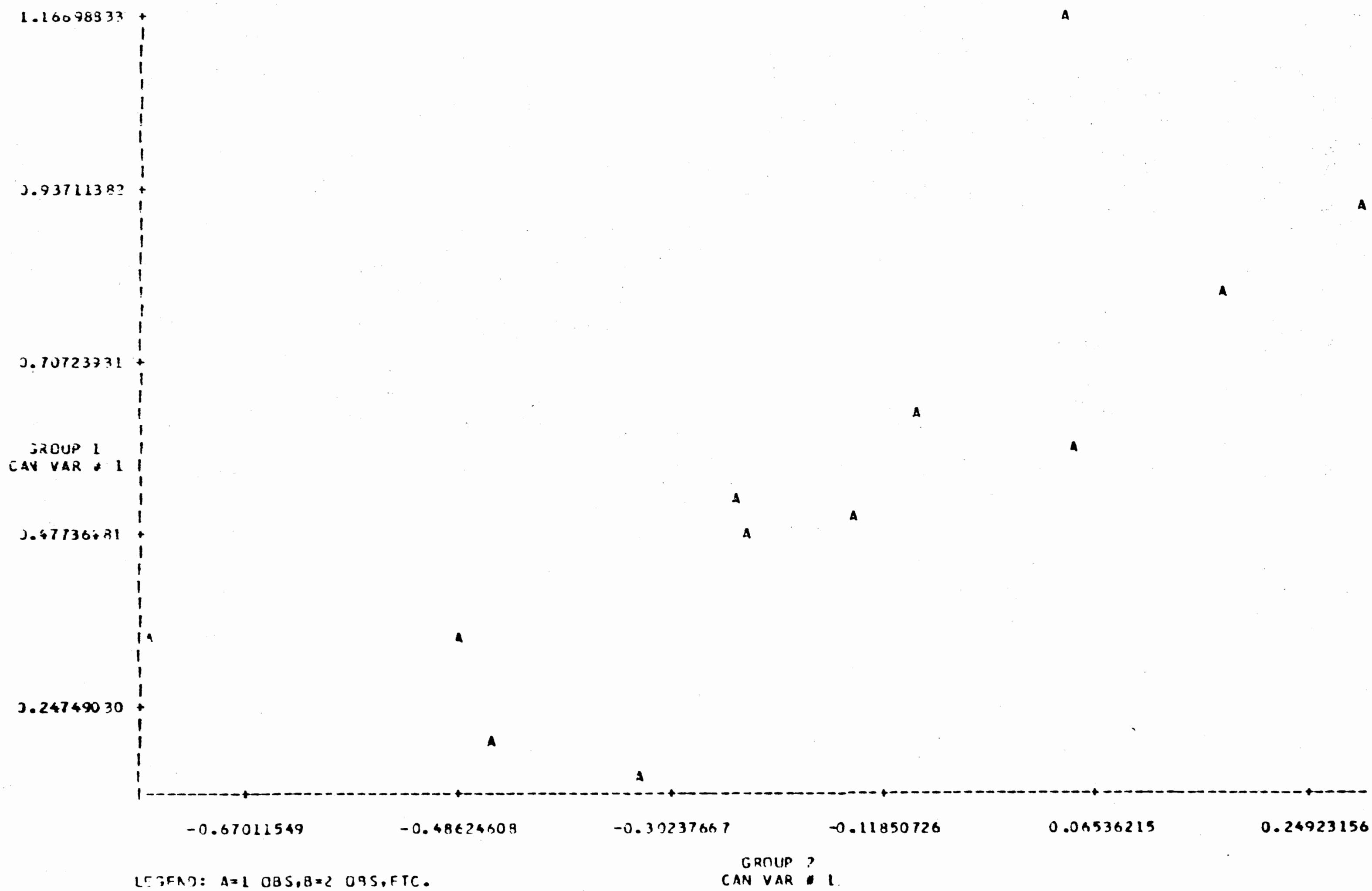


Figure 3.24. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Third Group, Third Set of Variables.

TABLE 3.26

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, FOURTH GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.33208148	-1.17007771	0.66593324	15.57134	12	0.2111
2	0.70264250	-0.40983566	0.60693275	4.48609	6	0.6132
3	0.26905642	0.40528923	0.31040489	0.81052	2	0.6724

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCP	BGR	ASC	AHA
VAR # 1	0.096759	0.706238	-0.178923	-0.554376
VAR # 2	-0.095284	0.689423	0.392014	0.574223
VAR # 3	-0.008868	-0.149182	0.788492	-0.337982

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	-0.590400	-0.673132	-0.873179
VAR # 2	0.760388	0.623449	-0.324314
VAR # 3	-0.270625	0.397750	0.363838

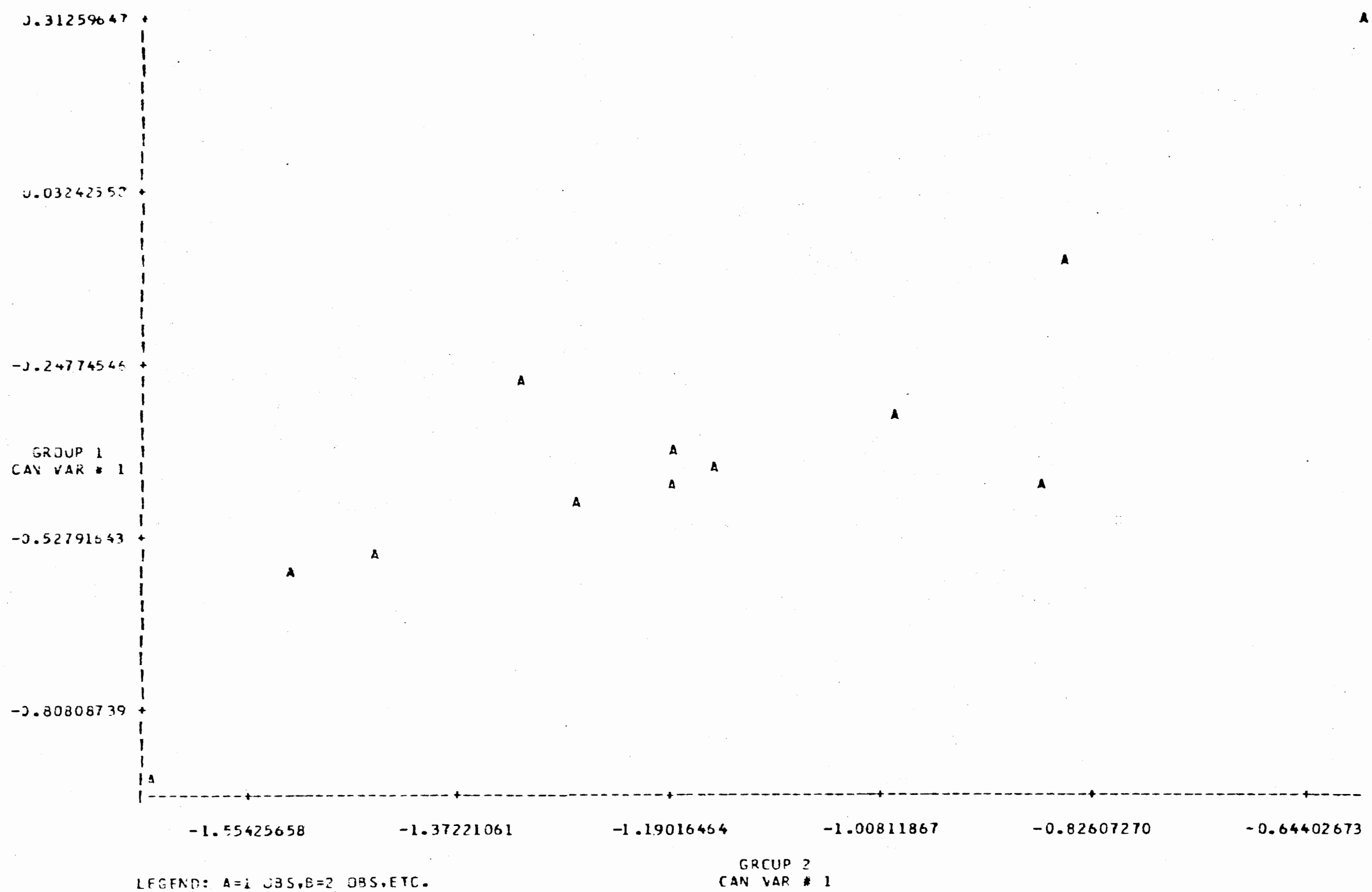


Figure 3.25. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Fourth Group, First Set of Variables.

TABLE 3.27

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, FOURTH GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.06464039	1.20982415	0.75527797	7.85212	12	0.7975
2	0.26787428	0.44780246	0.32437518	1.09208	6	0.9803
3	0.43184029	0.19262647	0.15616366	0.20267	2	0.8976

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	-0.143786	0.885716	-0.050873	-0.552935
VAR # 2	-0.557858	-0.025955	0.922104	-0.554978
VAR # 3	0.817379	0.299371	0.380799	0.224983

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	0.540165	0.672261	0.907636
VAR # 2	-0.940642	-0.502069	0.371297
VAR # 3	-0.039270	0.544027	0.195794

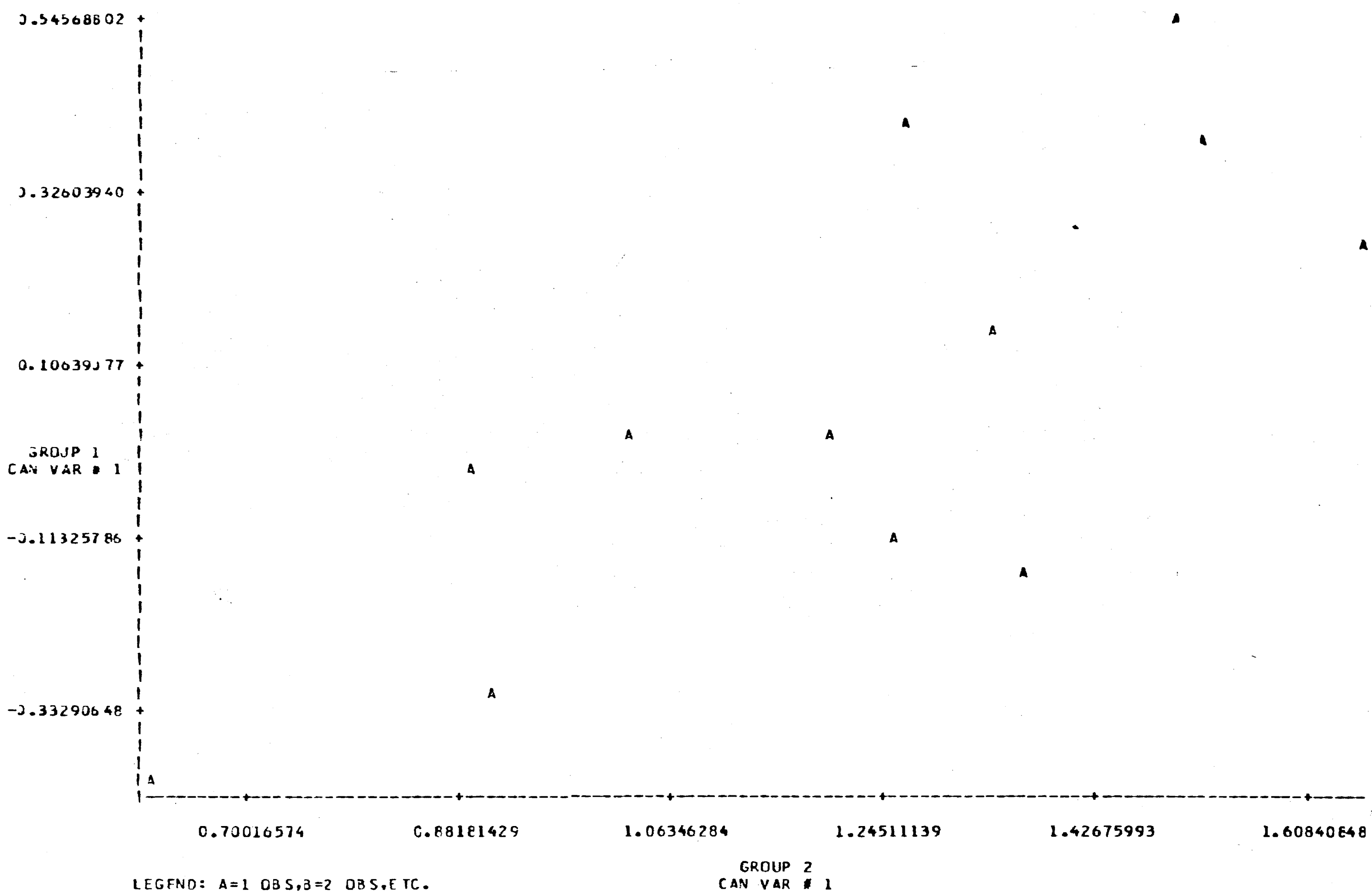


Figure 3.26. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Fourth Group, Second Set of Variables.

TABLE 3.28

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, FOURTH GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.42381613	0.73243507	0.80499203	9.20597	9	0.4187
2	0.34705371	-0.87144147	0.18684815	0.33062	4	0.9846
3	0.56301362	0.63673786	0.05792131	0.02856	1	0.8417

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.081505	-0.410464	0.650784
VAR # 2	0.396573	0.778856	0.271447
VAR # 3	-0.000694	0.474239	0.709082

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	-0.627190	-0.038554	0.603571
VAR # 2	-0.774200	-0.977953	-0.659935
VAR # 3	0.085130	-0.205237	0.447424

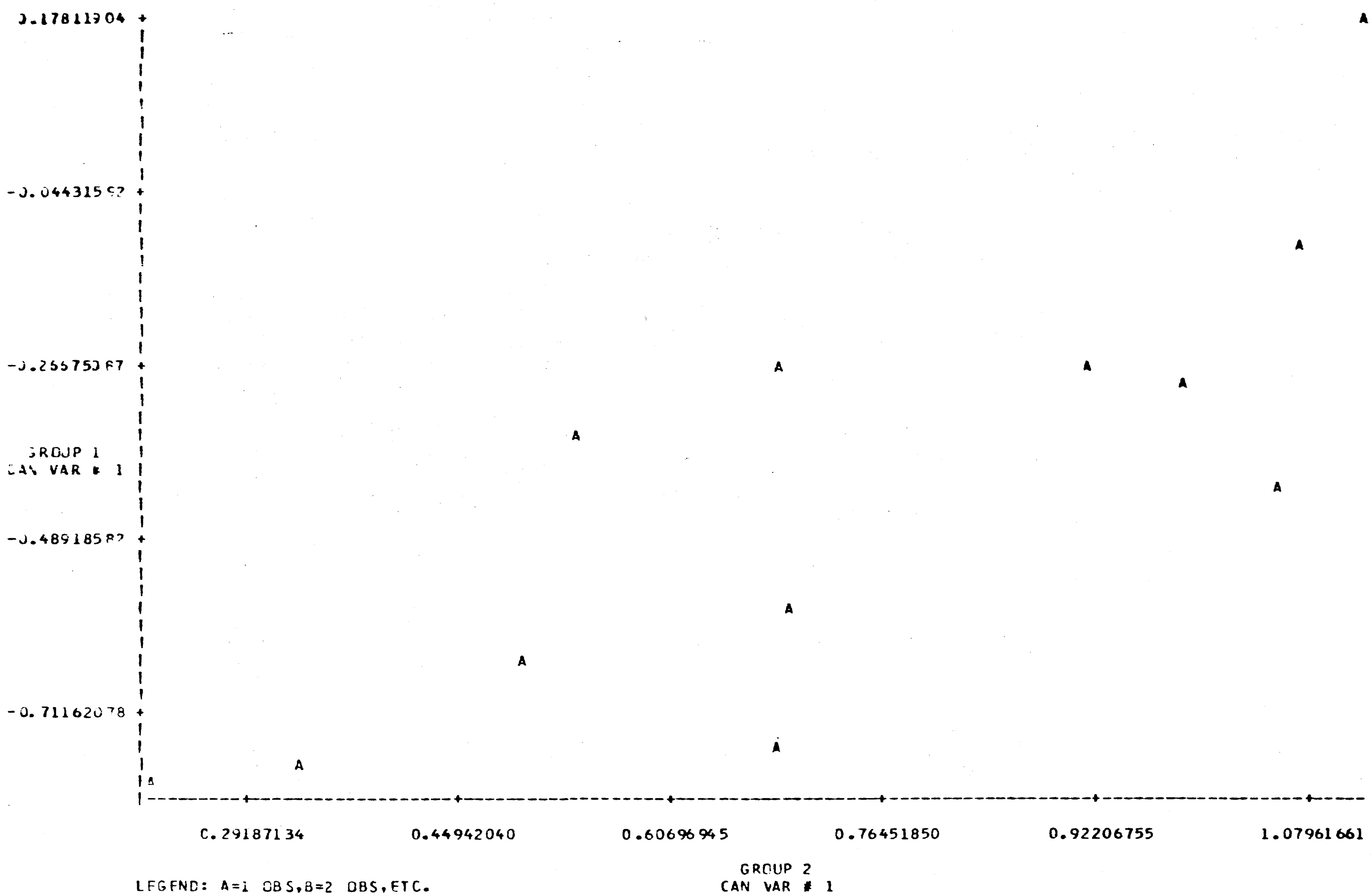


Figure 3.27. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Fourth Group, Third Set of Variables.

Fifth Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Fs and Vfs. The canonical correlation of the first variates of this set was .82 (Table 3.29) (Prob>Chi-SQ = .1684). This can be interpreted as high Bgr values (.72), moderately low Asc values (-.37), and moderately low Aha values (-.33) are highly associated with very high Fs values (.82) and high Vfs values (.68) (Figure 3.28). In terms of the original data, high Bgr counts are associated with high percentages of Fs and Vfs.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Fs and Vfs. The canonical correlation of the first variates of this set was .83 (Table 3.30) (Prob>Chi-SQ = .0626). This can be explained as moderately high Pvi values (.59), moderately high Etr values (.53), moderately high Par values (.56), and low Pst values (-.64) are highly associated with low Fs values (-.53) and high Vfs values (.75) (Figure 3.29). In terms of the original data, it can be explained as high counts of Pvi, Etr, Par, and low counts of Pst are highly associated with high percentages of Vfs.

The Third Set of Variables. Other grasses, forbs, and shrubs with Fs and Vfs. The canonical correlation of the first variates of this set was .48 (Table 3.31) (Prob>Chi-SQ = .8701). This can be interpreted as low other grasses values (-.49) and very low forbs values (-.75) are associated with very low Fs values (-.97) (Figure 3.30). In terms of the original data, it can be explained as high counts of other grasses and forbs corresponds with high percentages of Fs.

TABLE 3.29

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS,
FIFTH GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.54396473	1.52205436	0.81693541	11.61350	8	0.1584
2	0.46787314	-0.54542437	0.48290738	2.25699	3	0.5241

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCP	SGR	ASC	AHA
VAR # 1	-0.041264	0.717309	-0.371132	-0.332619
VAR # 2	0.928140	-0.084195	-0.753329	-0.431683

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	0.819485	0.683603
VAR # 2	0.573101	-0.729854

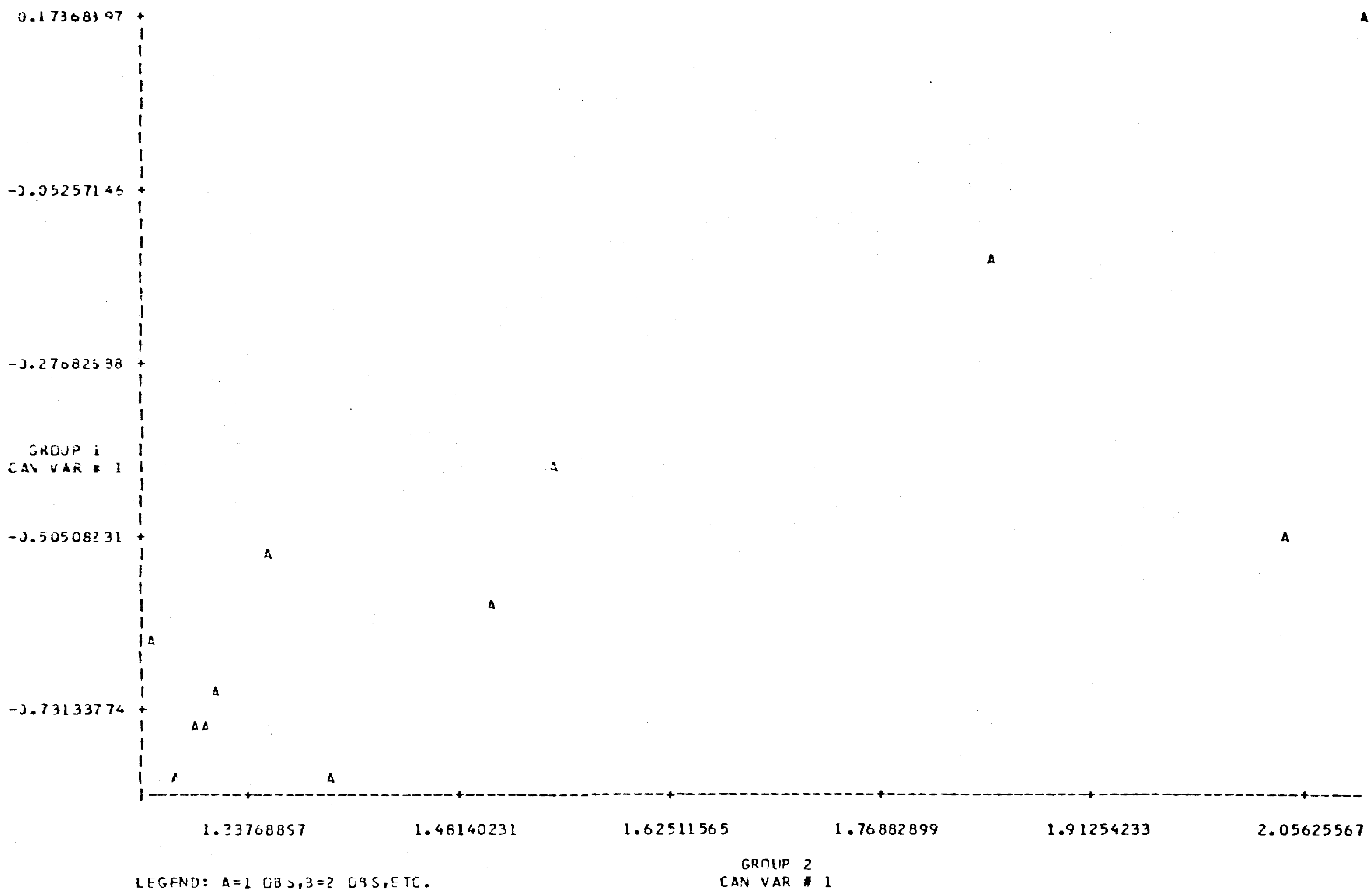


Figure 3.28. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Fifth Group, First Set of Variables.

TABLE 3.30

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS,
FIFTH GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.14054179	0.59519362	0.83418583	14.80487	8	0.0626
2	0.18948617	-1.50329032	0.65107120	4.68744	3	0.1945

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.585544	0.529381	-0.637220	0.563576
VAR # 2	-0.040429	0.793353	0.366474	-0.722086

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	-0.545836	0.751945
VAR # 2	-0.837892	-0.659226

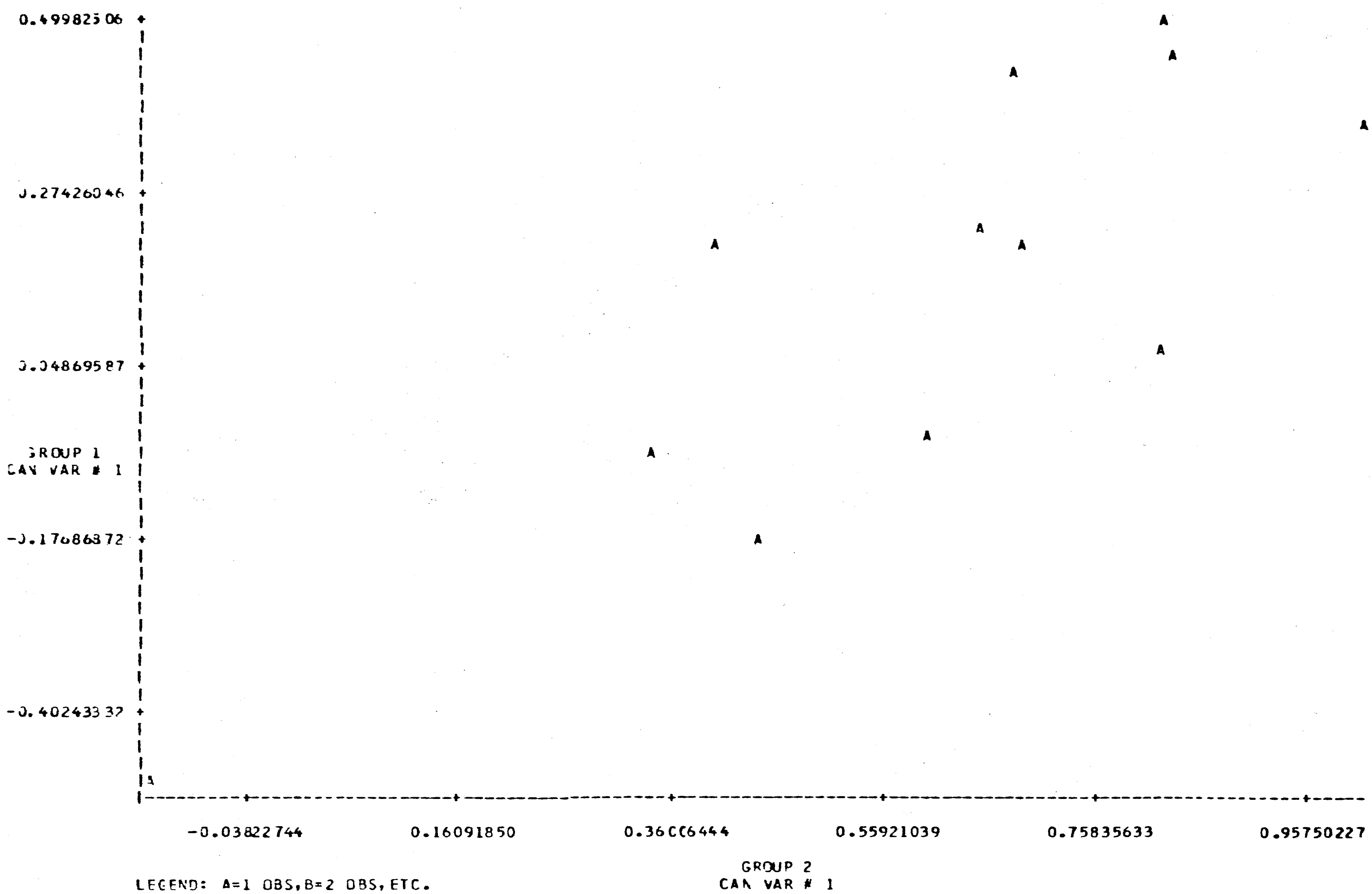


Figure 3.29. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Fifth Group, Second Set of Variables.

TABLE 3.31

CANONICAL CORRELATION ANALYSIS FOR B HORIZONS, FIFTH GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.51878925	-0.56176116	0.47583716	2.49155	6	0.8701
2	-0.02209705	1.51610080	0.14110317	0.18100	2	0.9065

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	-0.493129	-0.754693	0.417771
VAR # 2	0.860811	0.349003	0.504198

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	-0.965984	0.116889
VAR # 2	0.258600	0.992908

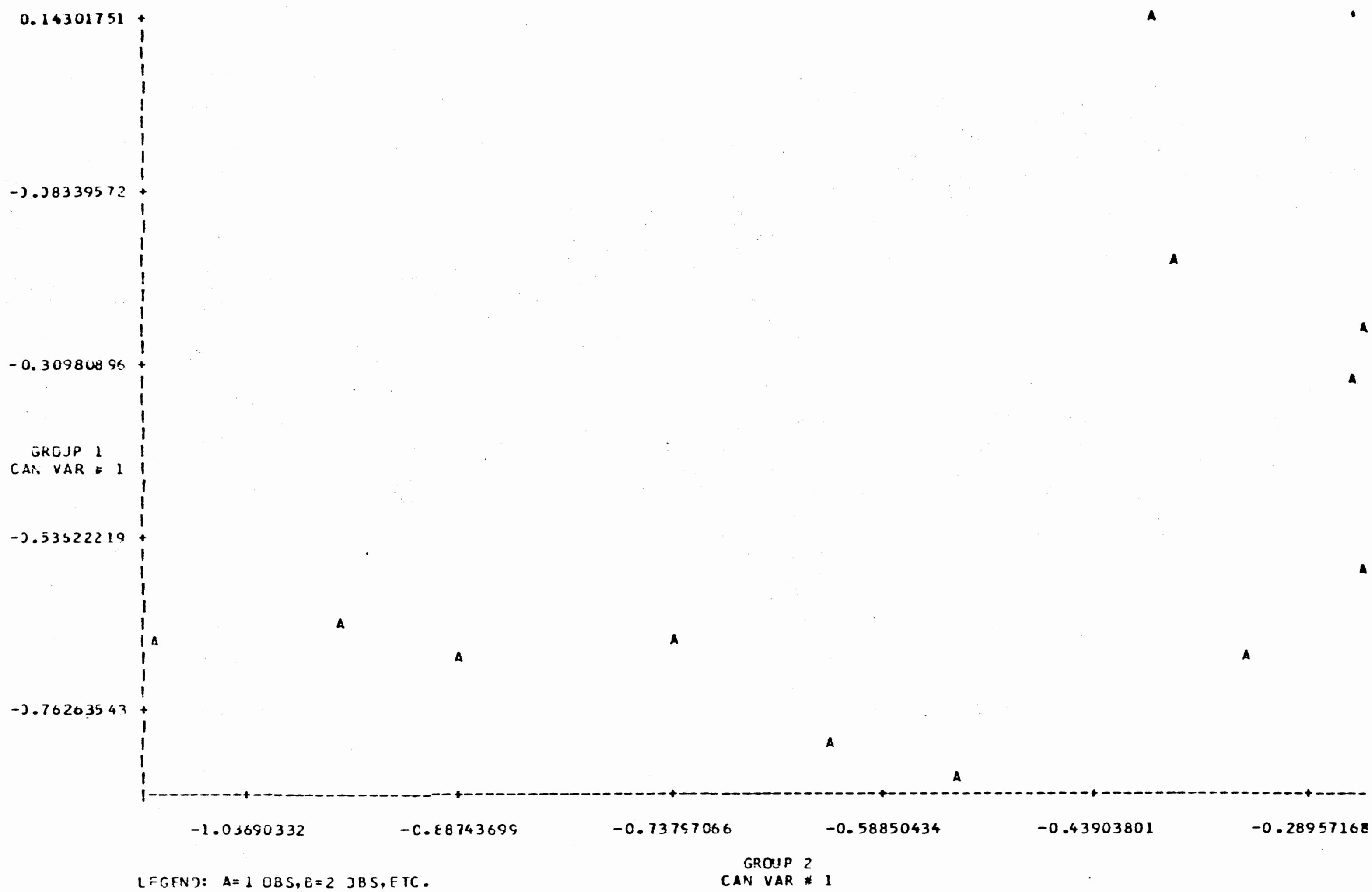


Figure 3.30. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for B Horizons, Fifth Group, Third Set of Variables.

Bt Horizons

First Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with thickness, pH, and OM. The canonical correlation of the first variates of this set was 1.0 (Table 3.32) (Prob>Chi-SQ = .0001). This can be interpreted as high Bgr values (.98), moderately high Scr values (.32), and low Asc values (-.28) are perfectly associated with high thickness values (.78) (Figure 3.31). In terms of the original data, it can be explained as high counts of Bgr and Scr are highly associated with thicker Bt horizons.

The Second Set of Variables. Pvi, Etr, Pst, and Par with thickness, pH, and OM. The canonical correlation of the first variates of this set was 1.0 (Table 3.33) (Prob>Chi-SQ = .0001). This can be explained as high Etr values (.80), moderately high Pst values (.53), and moderately high Pvi values (.47) are perfectly associated with very low thickness values (-.80), very low pH values (-.62), and high OM values (.77) (Figure 3.32). In terms of the original data, it can be explained as high counts of Etr, Pst, and Pvi are highly associated with high values of organic matter.

The Third Set of Variables. Other grasses, forbs, and shrubs with thickness, pH, and OM. The canonical correlations of the first variates of this set was .99 (Table 3.34) (Prob>Chi-SQ = .0584). This can be interpreted as moderately low other grasses values (-.30) are highly associated with moderately low pH values (-.13) and moderately high OM values (.51) (Figure 3.33). In terms of the original data, it can be

TABLE 3.32

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, FIRST GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.43477192	6.53418354	1.00000000	100.14026	12	0.0001
2	0.61271044	-13.11750921	0.91885686	4.54110	6	0.6058
3	0.63421235	2.28236856	0.57617932	1.21032	2	0.5514

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	0.315029	0.979990	-0.276084	-0.114605
VAR # 2	-0.661873	0.116423	0.831850	0.546614
VAR # 3	0.032332	-0.074388	-0.423905	0.739751

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	CM
VAR # 1	0.783151	-0.076799	0.190173
VAR # 2	0.523836	-0.315372	-0.126534
VAR # 3	0.335068	0.945855	-0.973562

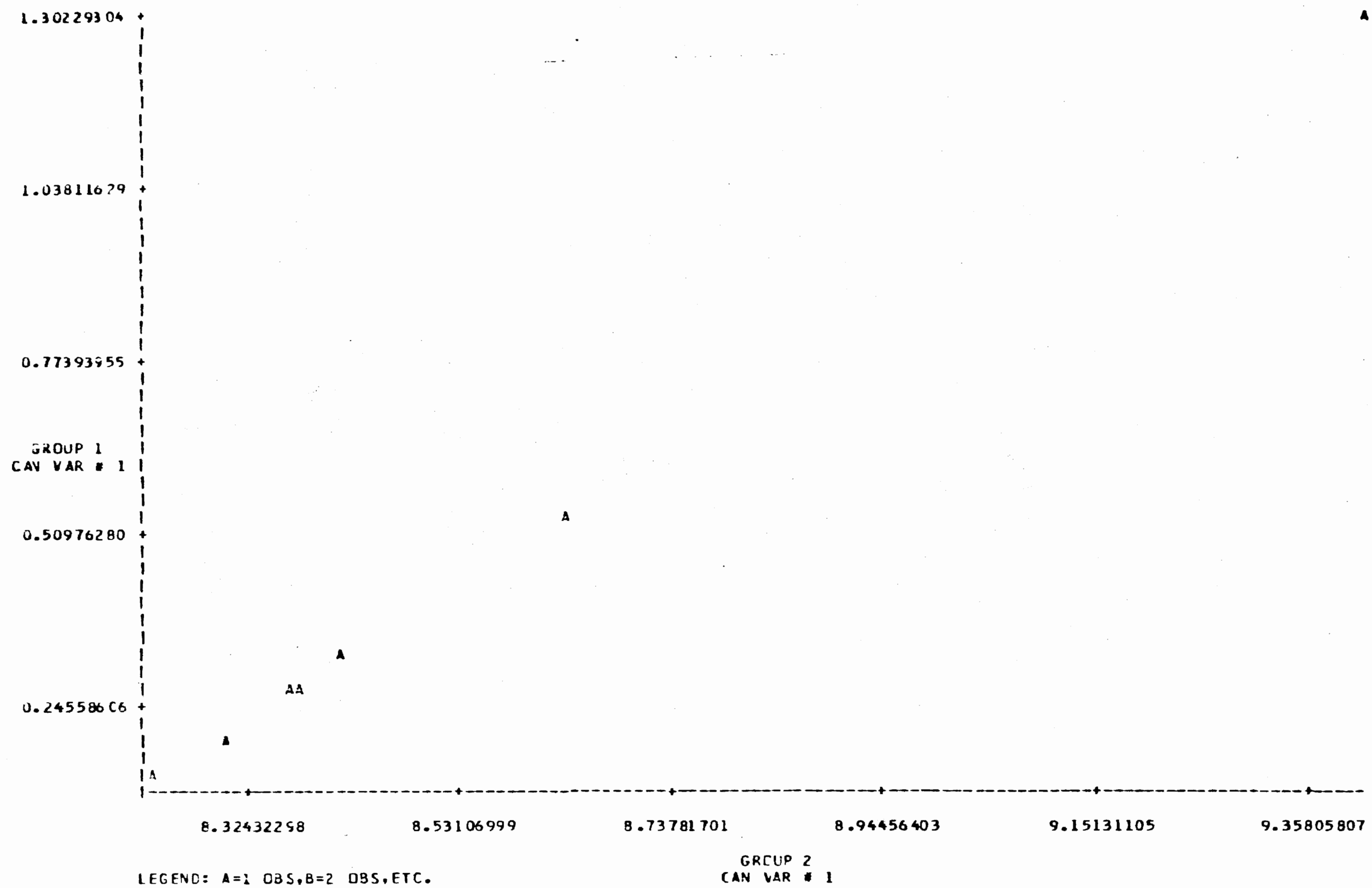


Figure 3.31. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, First Group, First Set of Variables.

TABLE 3.33

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, FIRST GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.66434167	-0.26495797	1.00000000	105.57813	12	0.0001
2	0.05091970	0.79891379	0.77052069	4.01794	6	0.5764
3	0.28050805	15.79246899	0.59589439	1.31593	2	0.5229

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.466854	0.799076	0.532274	0.244304
VAR # 2	0.415310	-0.442282	-0.641467	0.541645
VAR # 3	-0.581699	-0.219873	0.106685	0.145720

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	OM
VAR # 1	-0.904751	-0.621724	0.770798
VAR # 2	0.593571	-0.684141	0.635271
VAR # 3	-0.007000	0.381328	0.047963

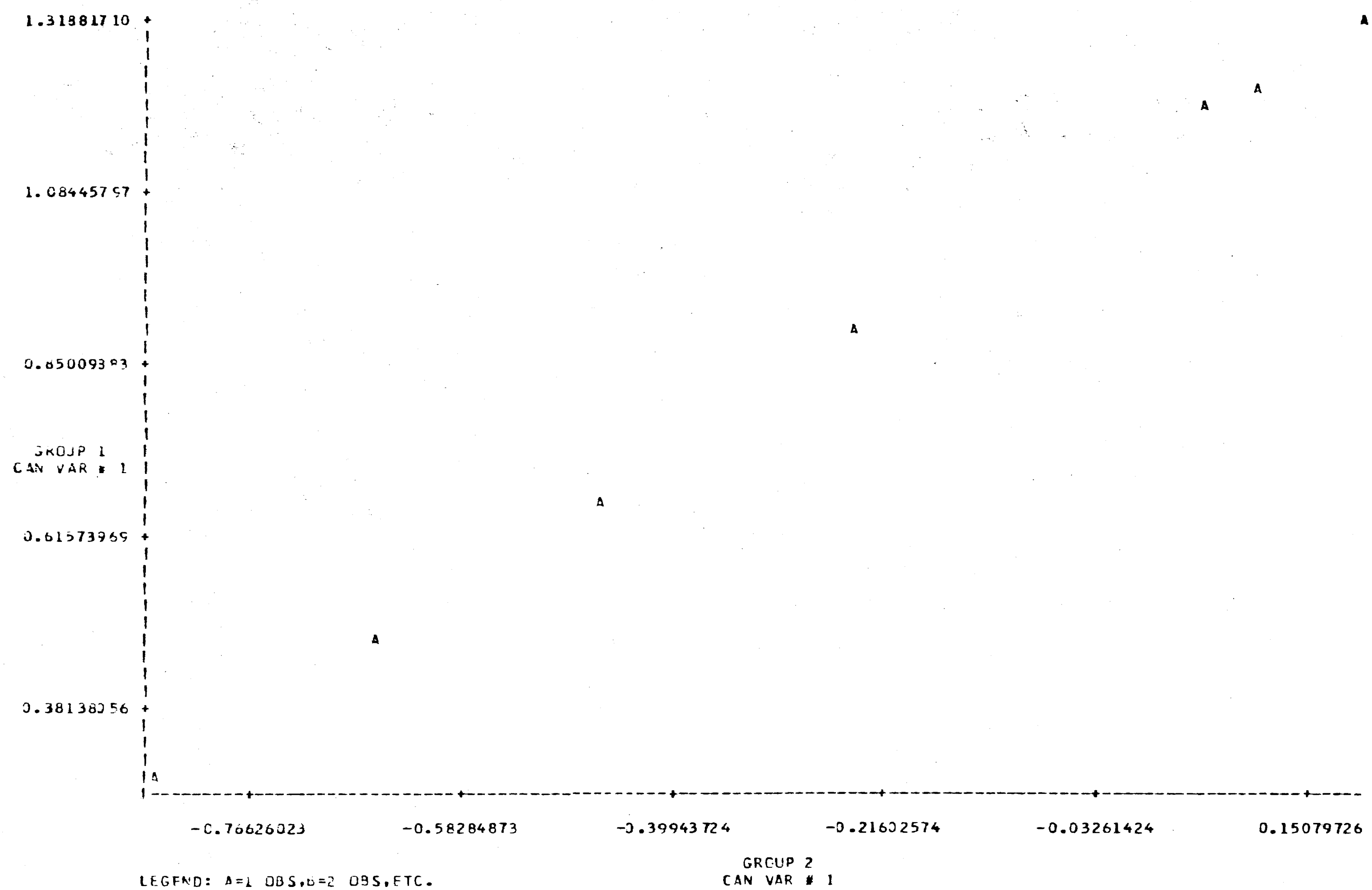


Figure 3.32. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, First Group, Second Set of Variables.

TABLE 3.34

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, FIRST GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.78459239	13.75088163	0.98819411	16.41064	9	0.0584
2	0.90691528	7.06347405	0.74289697	3.27888	4	0.5145
3	1.15481175	-3.16693244	0.35424887	0.46933	1	0.5005

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	-0.301063	-0.013471	-0.167707
VAR # 2	0.943532	0.978991	0.913053
VAR # 3	-0.138231	0.203458	-0.371765

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	OM
VAR # 1	0.099525	-0.134948	0.510523
VAR # 2	0.311117	0.966817	-0.859389
VAR # 3	0.945146	-0.207606	-0.028564

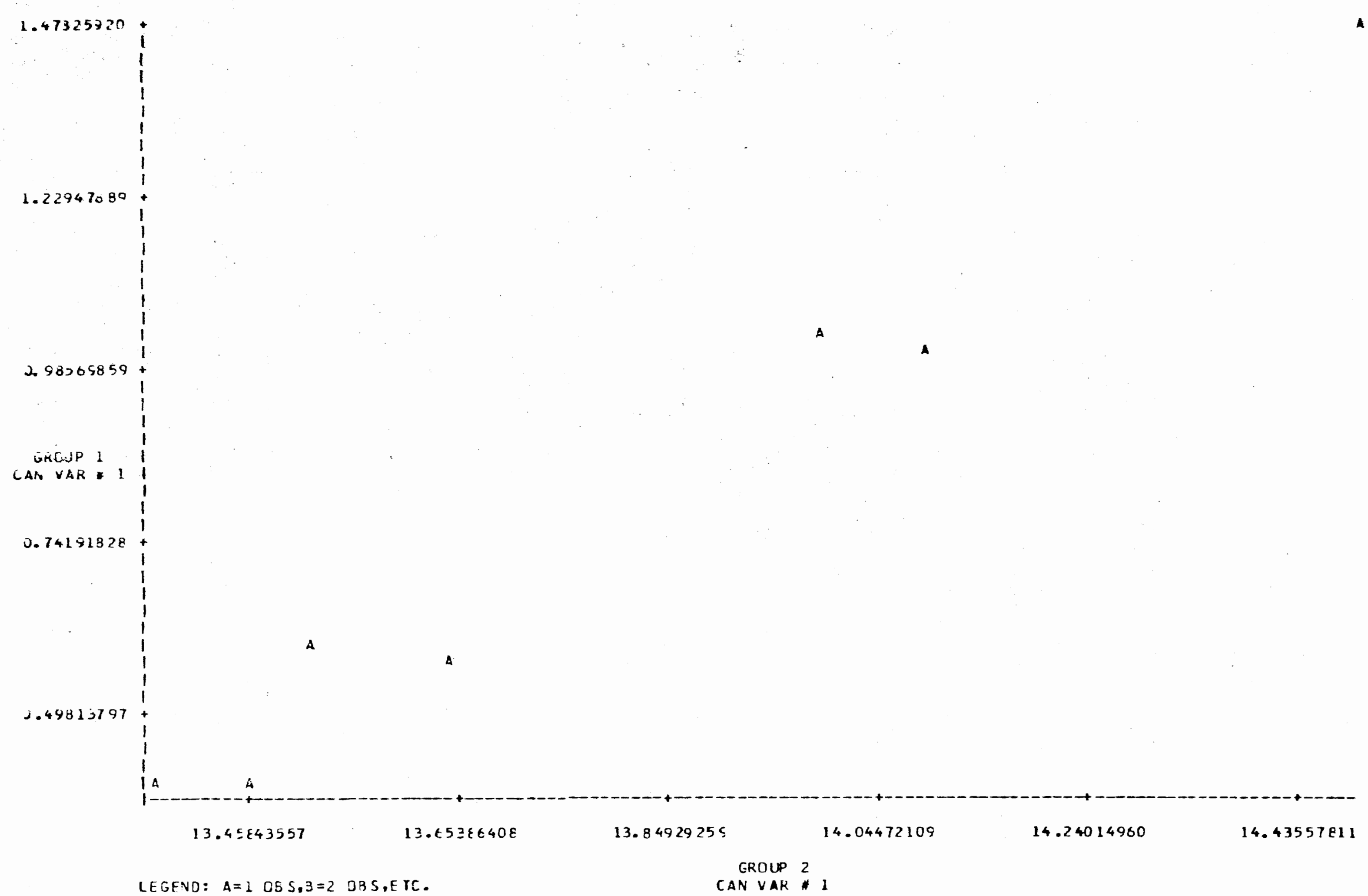


Figure 3.33. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, First Group, Third Set of Variables.

explained as high counts of other grasses are highly associated with higher values of pH.

Second Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Ca, Mg, and K. The canonical correlation of the first variates of this set was 1.0 (Table 3.35) (Prob>Chi-SQ = .0001). This can be explained as high Bgr values (.66), high Aha values (.65), and low Scr values (-.56) are perfectly associated with very low Ca values (-.99), low Mg values (-.56) and moderately low K values (-.30) (Figure 3.34). In terms of the original data, it can be explained as high Scr counts are highly associated with high values of Ca, Mg, and K.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Ca, Mg, and K. The canonical correlation of the first variates of this set was 1.0 (Table 3.36) (Prob>Chi-SQ = .0001). This can be interpreted as high Pst values (.94), moderately high Etr values (.55), and moderately low Par values (-.41) are perfectly associated with high Ca values (.97) and moderately high Mg values (.50) (Figure 3.35). In terms of the original data, it can be explained as high counts of Pst and Etr are highly associated with high values of Ca and Mg.

The Third Set of Variables. Other grasses, forbs, and shrubs with Ca, Mg, and K. The canonical correlation of the first variates of this set was .92 (Table 3.37) (Prob>Chi-SQ = .3798). This can be interpreted as moderately high forbs values (.45) are highly associated with low K values (-.75). No specific trend was noticed in terms of the data (Figure 3.36).

TABLE 3.35

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, SECOND GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.20978702	-1.32556749	1.00000000	103.14647	12	0.0001
2	1.64429119	-1.04817076	0.79708129	4.24572	6	0.5455
3	0.03933209	0.23023152	0.57791995	1.21936	2	0.5489

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BSR	ASC	AHA
VAR # 1	-0.558722	0.661134	0.193555	0.649236
VAR # 2	0.451033	0.036542	0.224453	0.115261
VAR # 3	-0.389248	-0.160550	0.929109	-0.239033

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	-0.985467	-0.563580	-0.270502
VAR # 2	0.007617	-0.209553	-0.601251
VAR # 3	0.169693	0.799040	0.751882

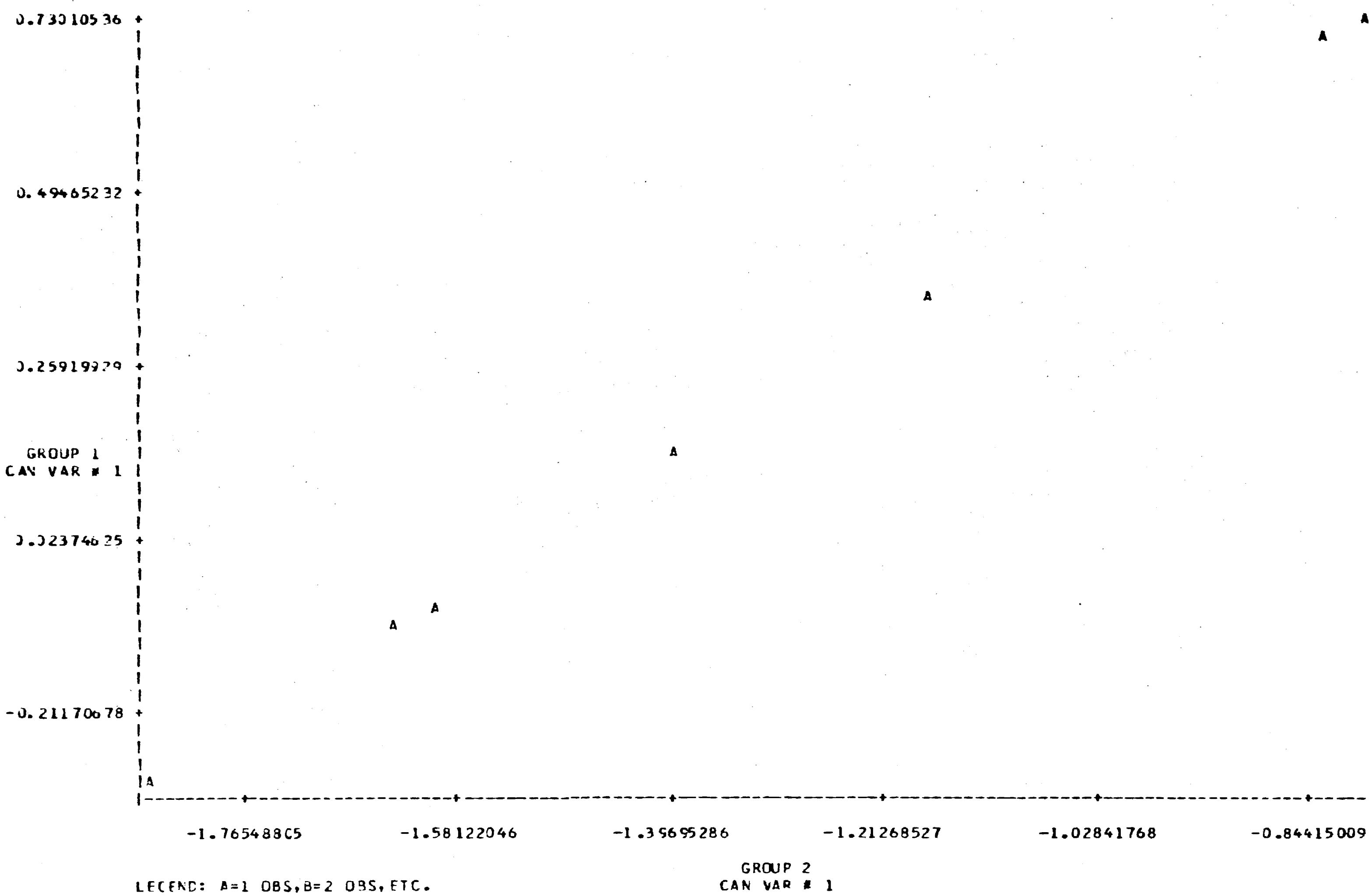


Figure 3.34. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Second Group, First Set of Variables.

TABLE 3.36

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, SECOND GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.62503144	1.17928540	1.00000000	999999.93750	12	0.0001
2	0.61878206	0.27904198	0.65109774	2.92341	6	0.8199
3	0.36655779	1.20009132	0.56727104	1.26884	2	0.5354

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	-0.159537	0.545684	0.942317	-0.409601
VAR # 2	0.927631	0.539936	0.118042	0.552917
VAR # 3	-0.056357	-0.543563	-0.049329	0.725463

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	0.970482	0.497170	0.162022
VAR # 2	0.214130	0.821483	0.757073
VAR # 3	0.110960	0.279264	0.632921

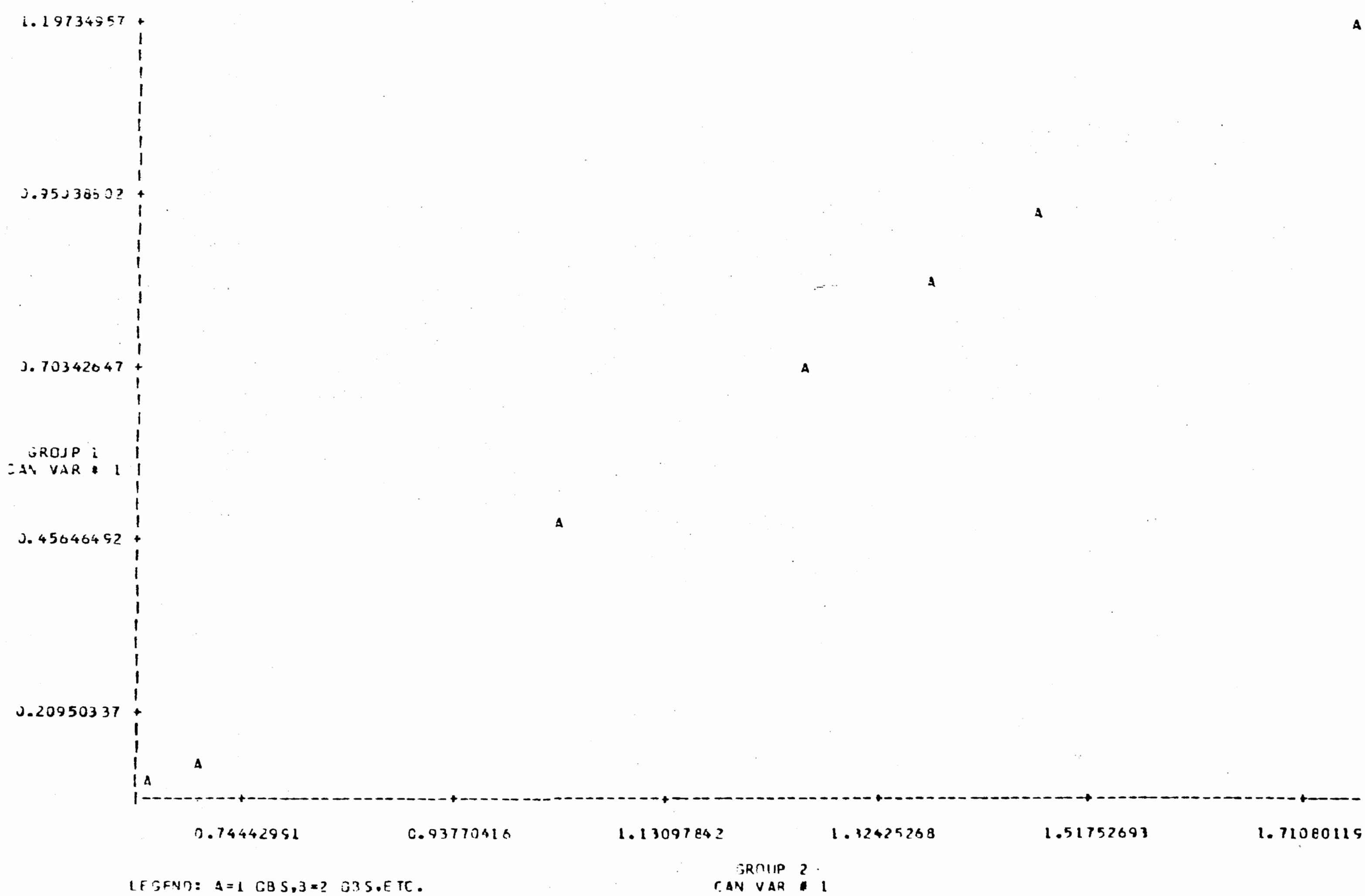


Figure 3.35. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Second Group, Second Set of Variables.

TABLE 3.37

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, SECOND GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	1.52674078	-1.38745686	0.91891527	9.64705	9	0.3798
2	0.63078082	0.33395810	0.76775575	3.13530	4	0.5379
3	0.20699971	-0.93393421	0.07435789	0.01941	1	0.8599

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.040032	0.445143	-0.146080
VAR # 2	0.819668	0.810677	0.906847
VAR # 3	-0.571438	-0.380330	-0.395333

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	-0.282028	-0.467410	-0.754829
VAR # 2	0.224202	-0.511919	-0.569063
VAR # 3	-0.932842	-0.720740	-0.326189

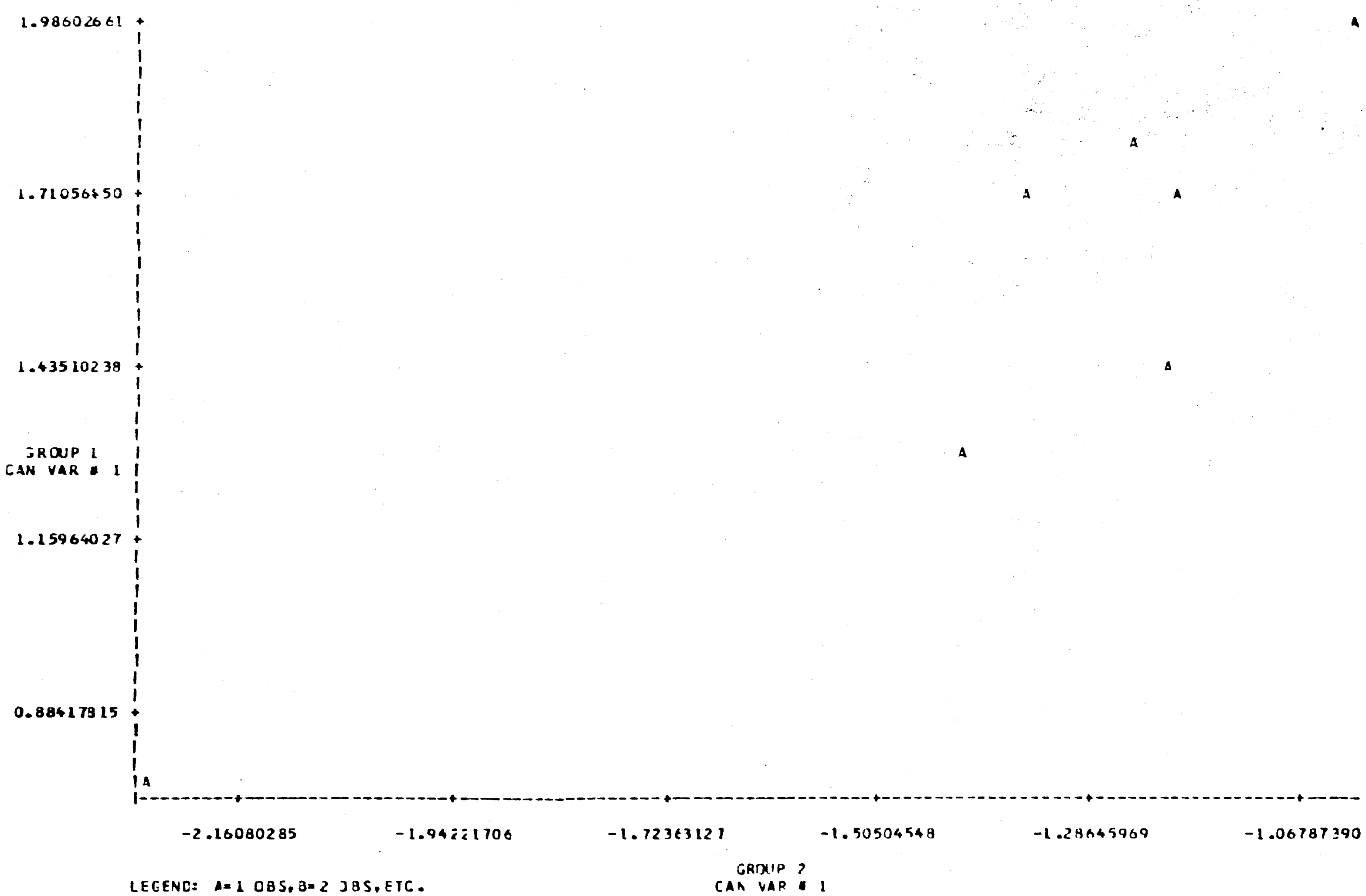


Figure 3.36. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Second Group, Third Set of Variables.

Third Group

<u>The First Set of Variables</u>. Scr, Bgr, Asc, and Aha with Na, CEC, and Clay. The canonical correlation of the first variates of this set was 1.0 (Table 3.38) (Prob>Chi-SQ = .001). This can be interpreted as high Aha values (.66) are perfectly associated with moderately low clay values (-.40) (Figure 3.37). No specific trend in terms of the original data exists.

<u>The Second Set of Variables</u>. Pvi, Etr, Pst, and Par with Na, CEC, and Clay. The canonical correlation of the first variates of this set was 1.0 (Table 3.39) (Prob>Chi-SQ = .0001). This can be interpreted as moderately low Etr values (-.57) are perfectly associated with moderately low clay values (-.35) and moderately low CEC values (-.28) (Figure 3.38). In terms of the original data, it can be explained as high Etr counts correspond to high values of Clay content and CEC.

<u>The Third Set of Variables</u>. Other grasses, forbs, and shrubs with Na, CEC, and Clay. No significant correlation can be seen in this set.

Fourth Group

<u>The First Set of Variables</u>. Scr, Bgr, Asc, and Aha with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was 1.0 (Table 3.40) (Prob>Chi-SQ = .0001). This can be explained as high Aha values (.88), moderately high Asc values (.52), and very low Scr values (-.65) are perfectly associated with high Cs values (.96) and high Ms values (.73) (Figure 3.39). In terms of the original data, it can be explained as high counts of Aha and Asc are highly associated with high percentages of Cs and Ms.

TABLE 3.38

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, THIRD GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	1.36973750	-1.74103517	1.00000000	99.84642	12	0.0001
2	0.69003947	3.12903207	0.90637013	5.88266	6	0.4371
3	-0.04063620	0.48921877	0.45994101	0.71304	2	0.7052

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCP	BGR	ASC	AHA
VAR # 1	-0.043464	0.002617	0.257613	0.660836
VAR # 2	0.287358	-0.080403	0.660495	-0.602756
VAR # 3	-0.424525	0.809457	0.305479	0.172715

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	0.049445	-0.176906	-0.400479
VAR # 2	0.193914	0.332688	0.200253
VAR # 3	0.979772	-0.906782	-0.894156

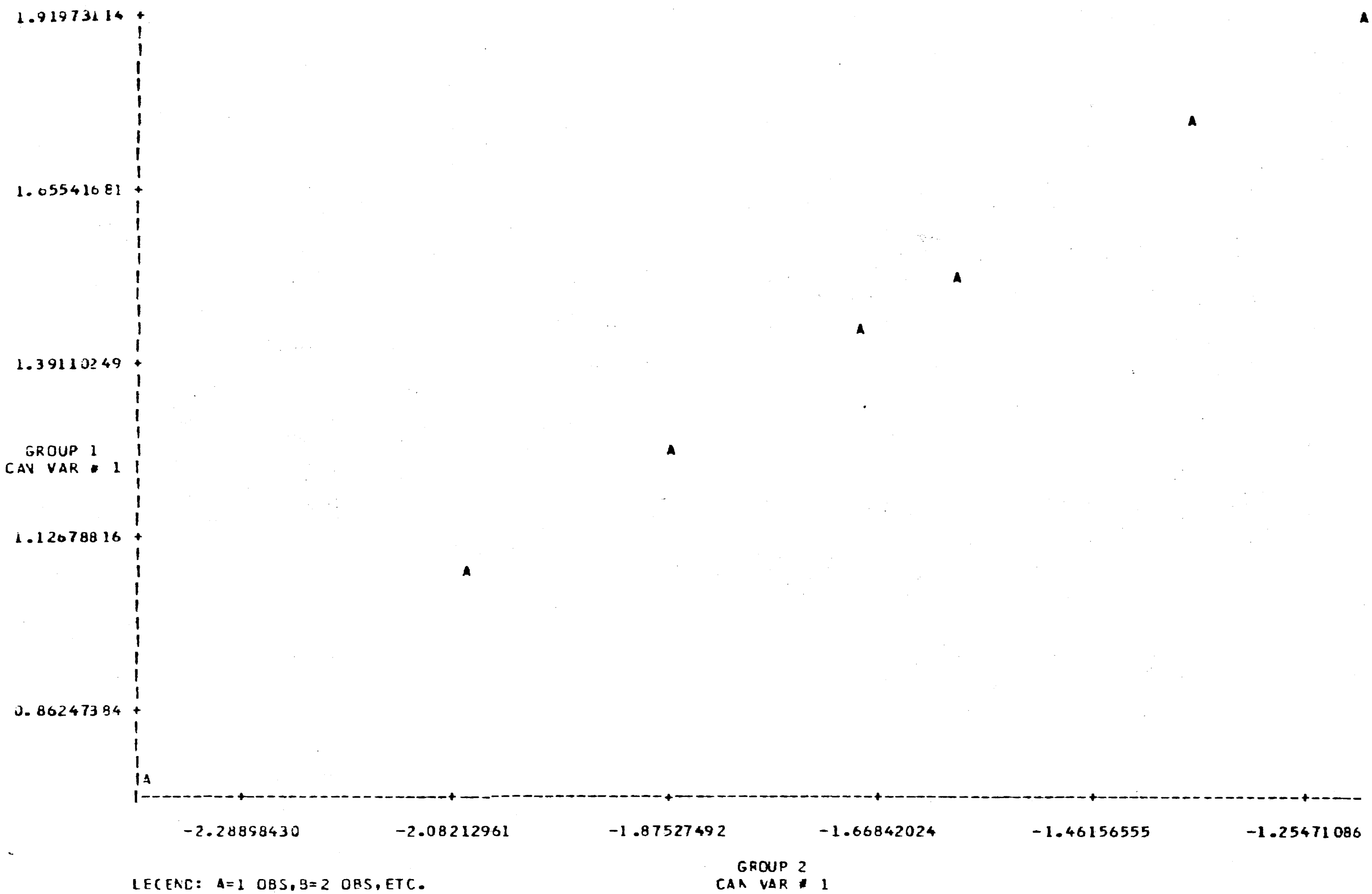


Figure 3.37. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Third Group, First Set of Variables.

TABLE 3.39

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, THIRD GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.03390947	2.97945152	1.00000000	104.63155	12	0.0001
2	0.91115789	1.67147535	0.96311520	8.43964	6	0.2066
3	0.28048404	1.17516029	0.41377596	0.56337	2	0.7581

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVT	ETR	PST	PAR
VAR # 1	0.364964	-0.572697	0.278039	0.221097
VAR # 2	0.242658	0.339211	0.436733	0.555270
VAR # 3	0.167265	0.704427	0.815592	-0.681589

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	0.770904	-0.283256	-0.345642
VAR # 2	-0.482745	0.630157	0.796879
VAR # 3	-0.415528	0.722958	0.495496

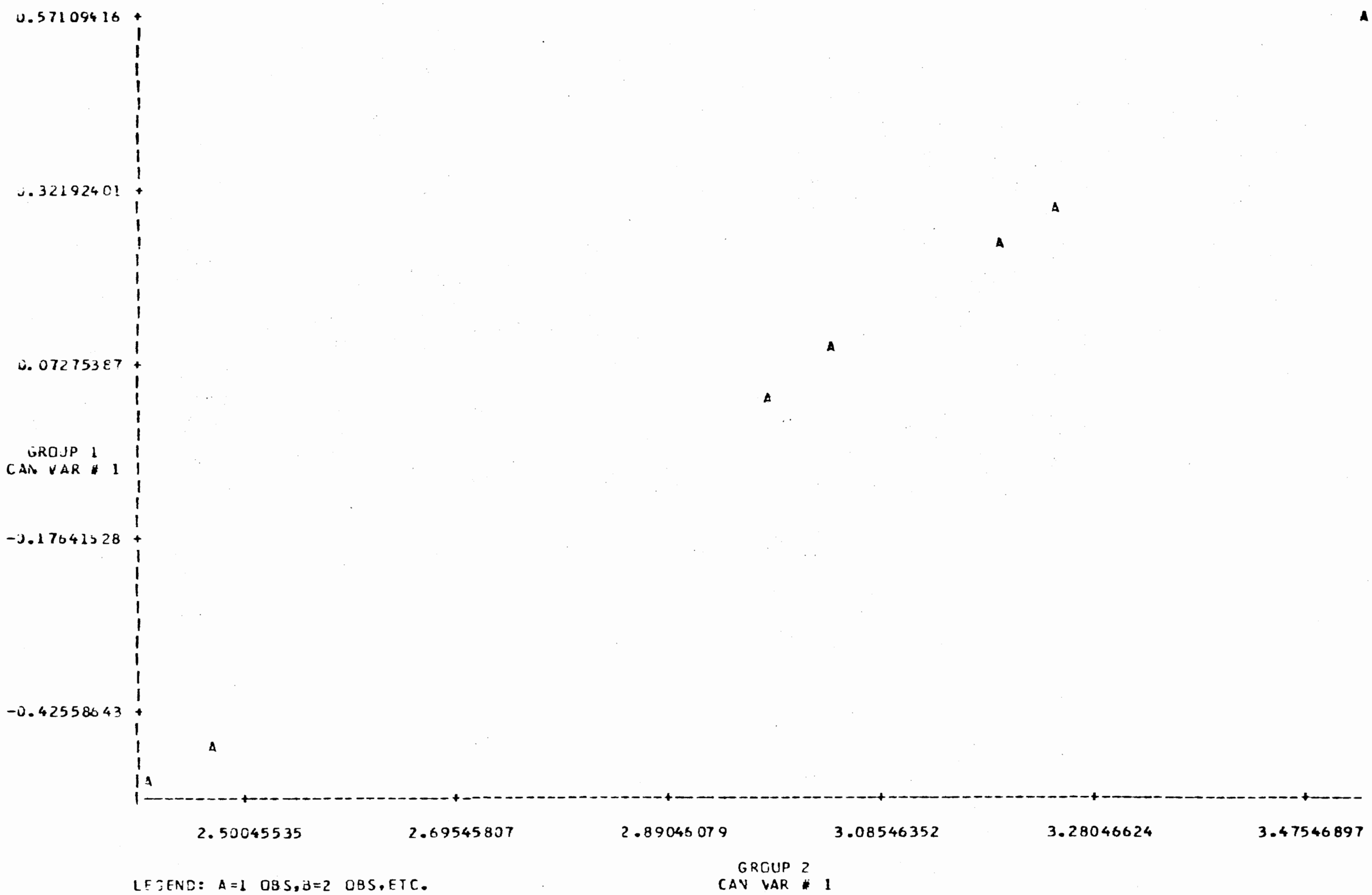


Figure 3.38. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Third Group, Second Set of Variables.

TABLE 3.40

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS
FOURTH GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.65986854	0.43742276	1.00000000	108.47574	12	0.0001
2	-0.04103012	-0.13511031	0.94915636	8.28862	6	0.2167
3	-0.49496309	0.58217972	0.60264508	1.35381	2	0.5130

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BSR	ASC	AHA
VAR # 1	-0.648220	-0.088333	0.516888	0.882329
VAR # 2	-0.228921	-0.344156	0.837838	-0.405448
VAR # 3	-0.380356	0.799256	0.123108	0.005346

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	0.502125	0.556605	0.716623
VAR # 2	0.801229	-0.037637	-0.339828
VAR # 3	0.325427	0.281560	0.609072

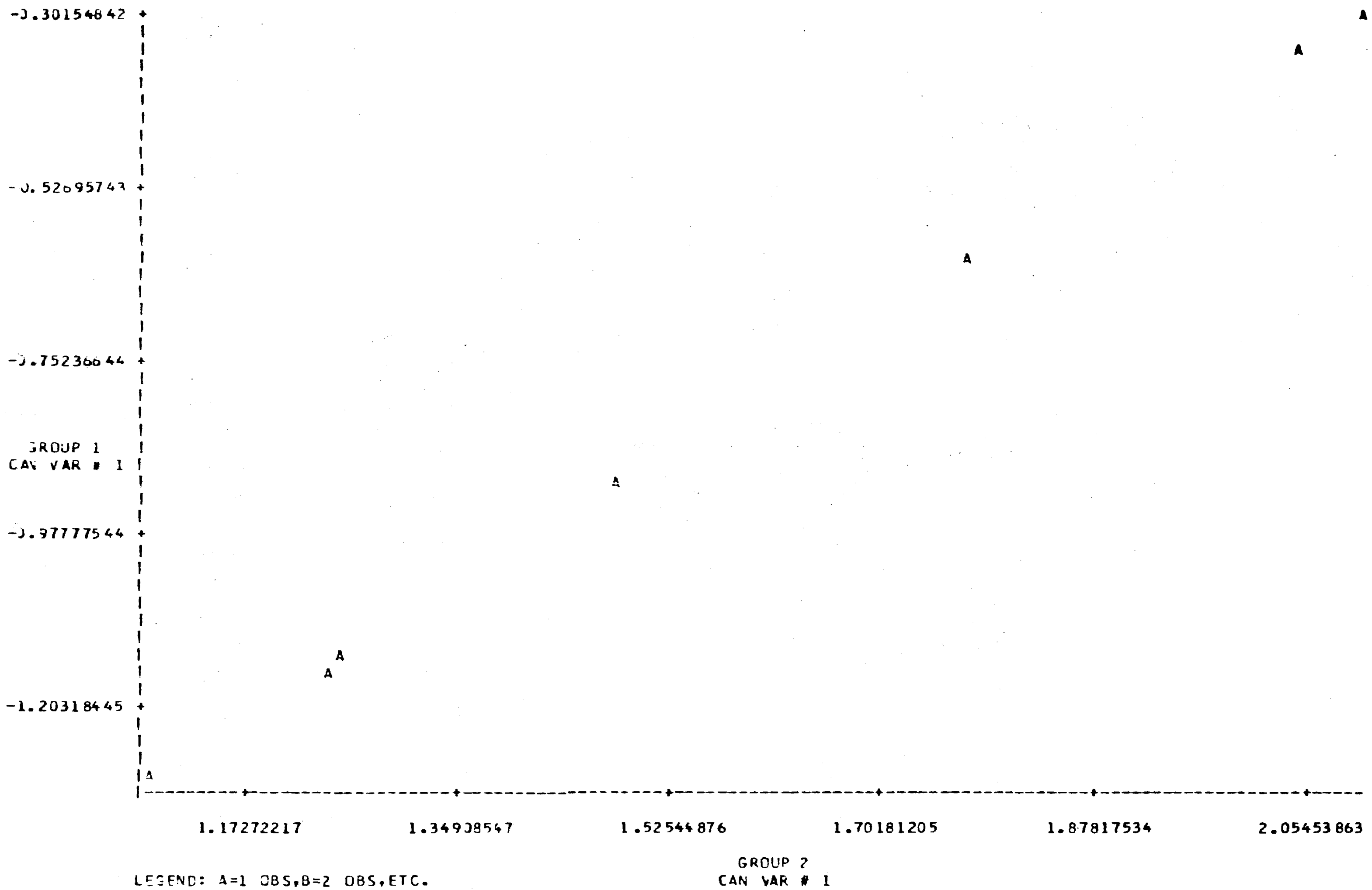


Figure 3.39. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Fourth Group, First Set of Variables.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was 1.0 (Table 3.41) (Prob>Chi-SQ = .0001). This can be interpreted as moderately high Pst values (.45) and moderately low Pvi values (-.43) are perfectly associated with very low Vcs values (-.73), very low Cs values (-.97), and very low Ms values (-.79) (Figure 3.40). This is true in terms of the original data, high counts of Pvi are highly associated with high percentages of Vcs, Cs, and Ms.

The Third Set of Variables. Other grasses, forbs and shrubs with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was 1.0 (Table 3.42) (Prob>Chi-SQ = .0447). No significant correlations were noticed in this set (Figure 3.41).

Fifth Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Fs and Vfs. The canonical correlation of the first variates of this set was .92 (Table 3.43) (Prob>Chi-SQ = .2156). This can be interpreted as moderately high Asc values (.58), moderately high Aha values (.50), and moderately low Bgr values (-.41) are highly associated with very low Vfs values (-.78) (Figure 3.42). In terms of the original data, it can be explained as high counts of Bgr are highly associated with high percentages of Vfs.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Fs and Vfs. The canonical correlation of the first variates of this set was .92 (Table 3.44) (Prob>Chi-SQ = .3068). This can be interpreted as high Par values (.65), and moderately low Etr values (-.47) are highly

TABLE 3.41

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS FOURTH GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.57533277	-0.56499172	1.00000000	112.09776	12	0.0001
2	0.67862771	-0.05458251	0.99113218	12.67930	6	0.0480
3	0.11060178	-0.46534554	0.41579264	0.56943	2	0.7559

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	-0.429433	-0.027423	0.448072	0.167750
VAR # 2	0.878220	0.340959	0.524294	0.406833
VAR # 3	-0.202608	0.686583	0.690170	-0.868034

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	-0.734873	-0.568519	-0.789031
VAR # 2	0.669525	-0.246023	-0.358658
VAR # 3	0.108151	-0.037997	-0.498753

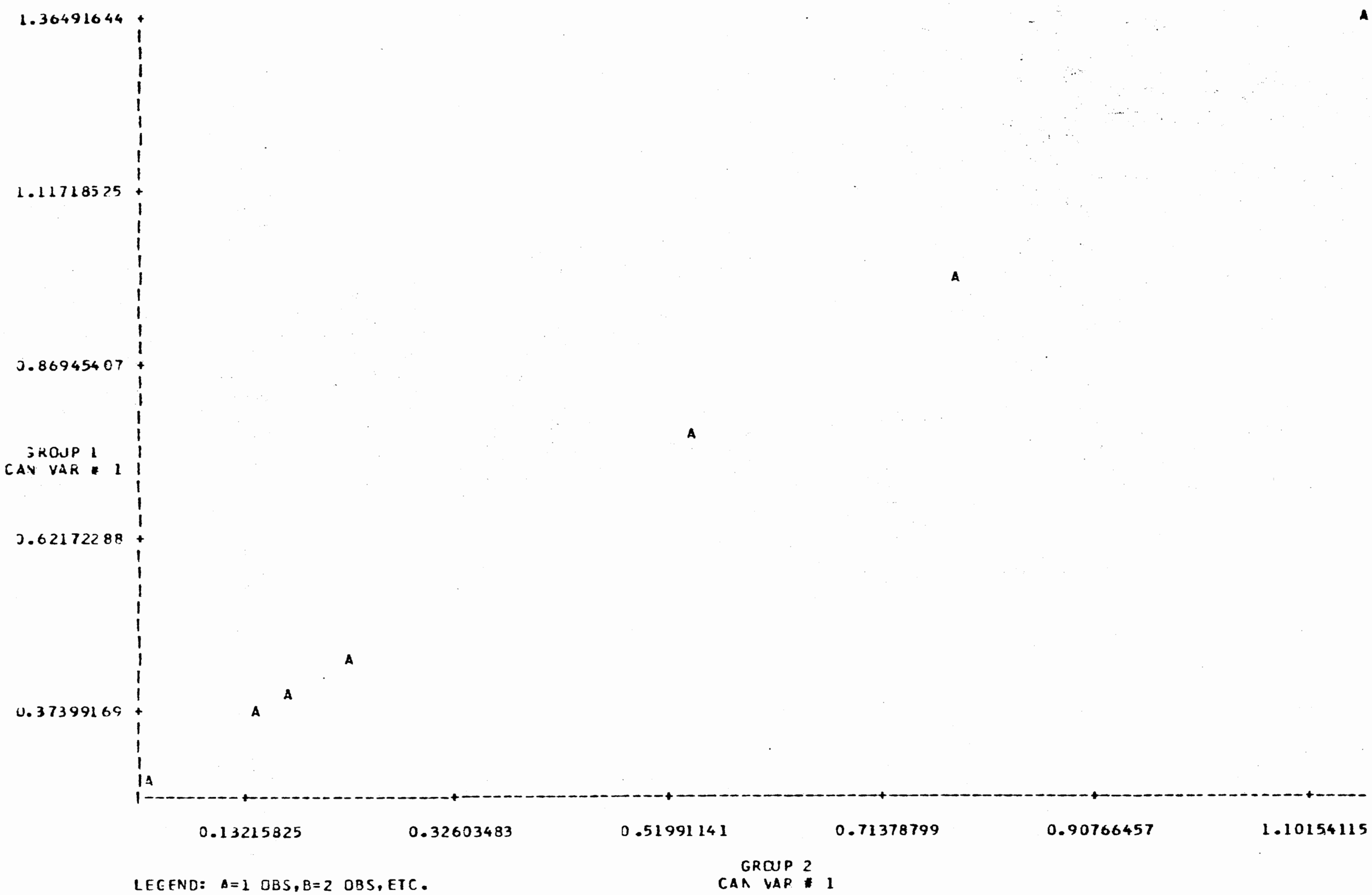


Figure 3.40. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Fourth Group, Second Set of Variables.

TABLE 3.42

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, FOURTH GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.26862274	0.02924946	0.99554229	17.24821	9	0.0447
2	1.63606428	0.51582554	0.39872170	0.72049	4	0.9464
3	0.15101727	-0.52673767	0.17940785	0.11451	1	0.7323

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	-0.048504	0.042896	0.173520
VAR # 2	0.198688	0.598981	0.043951
VAR # 3	0.978862	0.799614	0.983847

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	-0.320508	-0.575168	-0.141574
VAR # 2	-0.310157	0.561266	0.821007
VAR # 3	-0.995029	-0.595115	-0.553086

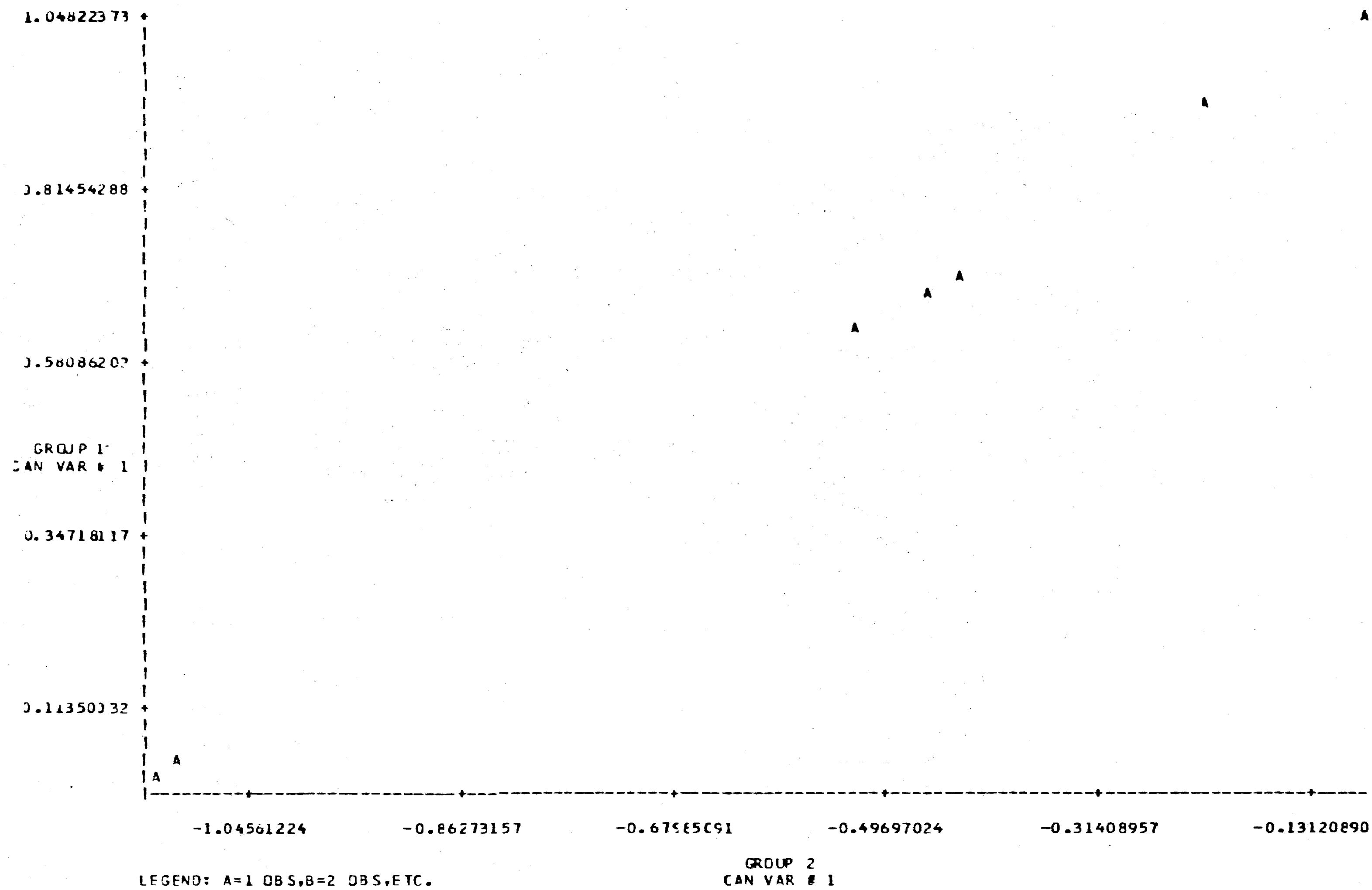


Figure 3.41. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Fourth Group, Third Set of Variables.

TABLE 3.43

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, FIFTH GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	1.13983370	-3.20128214	0.91823389	10.74794	8	0.2156
2	0.53326565	1.76057268	0.83921584	4.26424	3	0.2330

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	-0.168783	-0.409968	0.577893	0.499327
VAR # 2	-0.112208	0.768014	-0.230590	0.564616

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	-0.030689	-0.776487
VAR # 2	0.999529	-0.630133

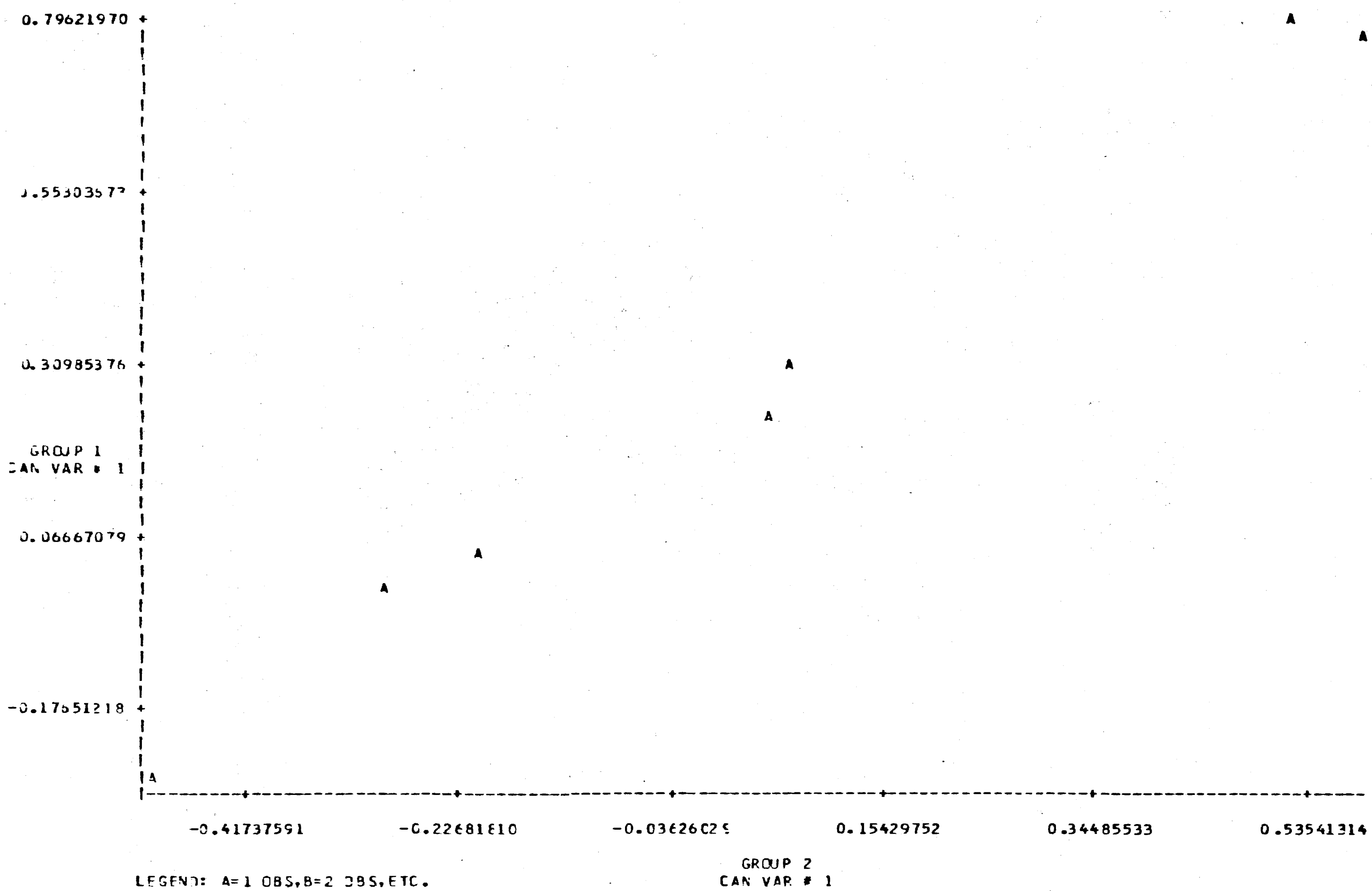


Figure 3.42. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Fifth Group, First Set of Variables.

TABLE 3.44

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, FIFTH GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.41847032	2.85842253	0.91859147	9.43144	8	0.3068
2	0.82150781	-2.27543320	0.75328042	2.93305	3	0.4034

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	-0.146234	-0.467577	0.026840	0.654436
VAR # 2	0.308986	0.775282	0.877756	-0.120933

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	-0.138350	0.871651
VAR # 2	-0.590383	0.490127

associated with high Vfs values (.87) (Figure 3.43), which means that a high Par count is highly associated with high percentages of Vfs, in terms of the original data.

The Third Set of Variables. Other grasses, forbs, and shrubs with Fs and Vfs. The canonical correlation of the first variates of this set was .87 (Table 3.45) (Prob>Chi-SQ = .3014) (Figure 3.44). No significant correlation can be noticed in this set.

C Horizons

First Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with thickness, pH, and OM. The canonical correlation of the first variates of this set was .92 (Table 3.46) (Prob>Chi-SQ = .4567). This can be interpreted as high Scr values (.75), moderately high Bgr values (.36) and moderately low Asc values (-.38) are highly associated with high thickness values (.58) and moderately low pH values (-.24) (Figure 3.45). In terms of the original data, high counts of Scr and Bgr are highly associated with thicker C horizons and high counts of Asc are highly associated with high pH values.

The Second Set of Variables. Pvi, Etr, Pst, and Par with thickness, pH, and OM. The canonical correlation of the first variates of this set was .92 (Table 3.47) (Prob>Chi-SQ = .2110). This can be interpreted as low Pst values (-.45) are highly associated with very low pH values (-.99), low OM values (-.52), and moderately low thickness values (-.32) (Figure 3.46). The best example, in terms of the original data, is in 11W where the Pst has a maximum count (13.0) and the pH value is in the

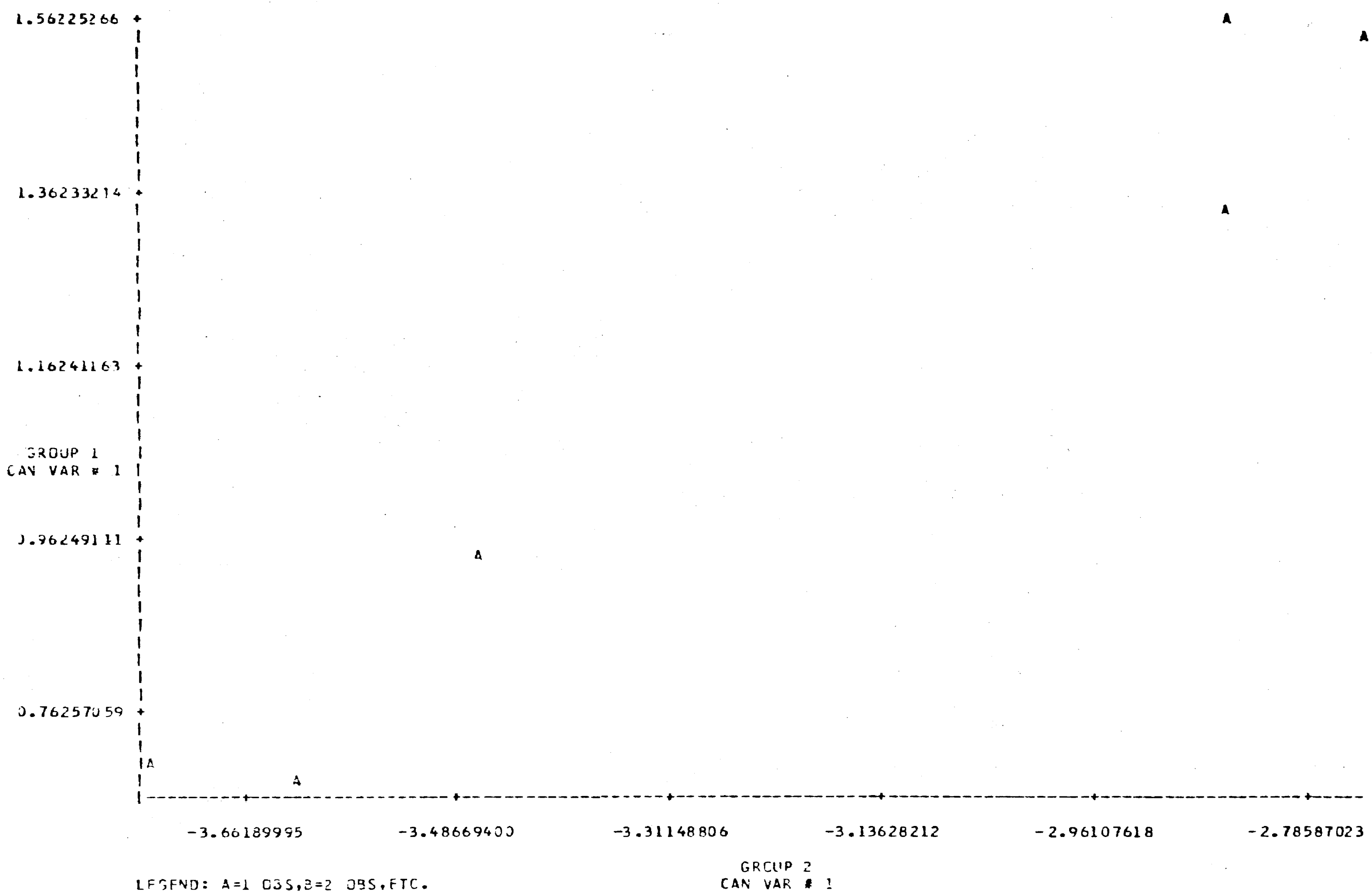


Figure 3.43. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Fifth Group, Second Set of Variables.

TABLE 3.45

CANONICAL CORRELATION ANALYSIS FOR Bt HORIZONS, FIFTH GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.82639179	2.74021926	0.86519164	7.20962	6	0.3014
2	1.43757332	2.41647967	0.58666735	1.68747	2	0.4332

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	-0.021074	-0.235531	0.246072
VAR # 2	0.206546	0.555603	0.229858

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	-0.188044	0.895225
VAR # 2	0.982161	-0.445614

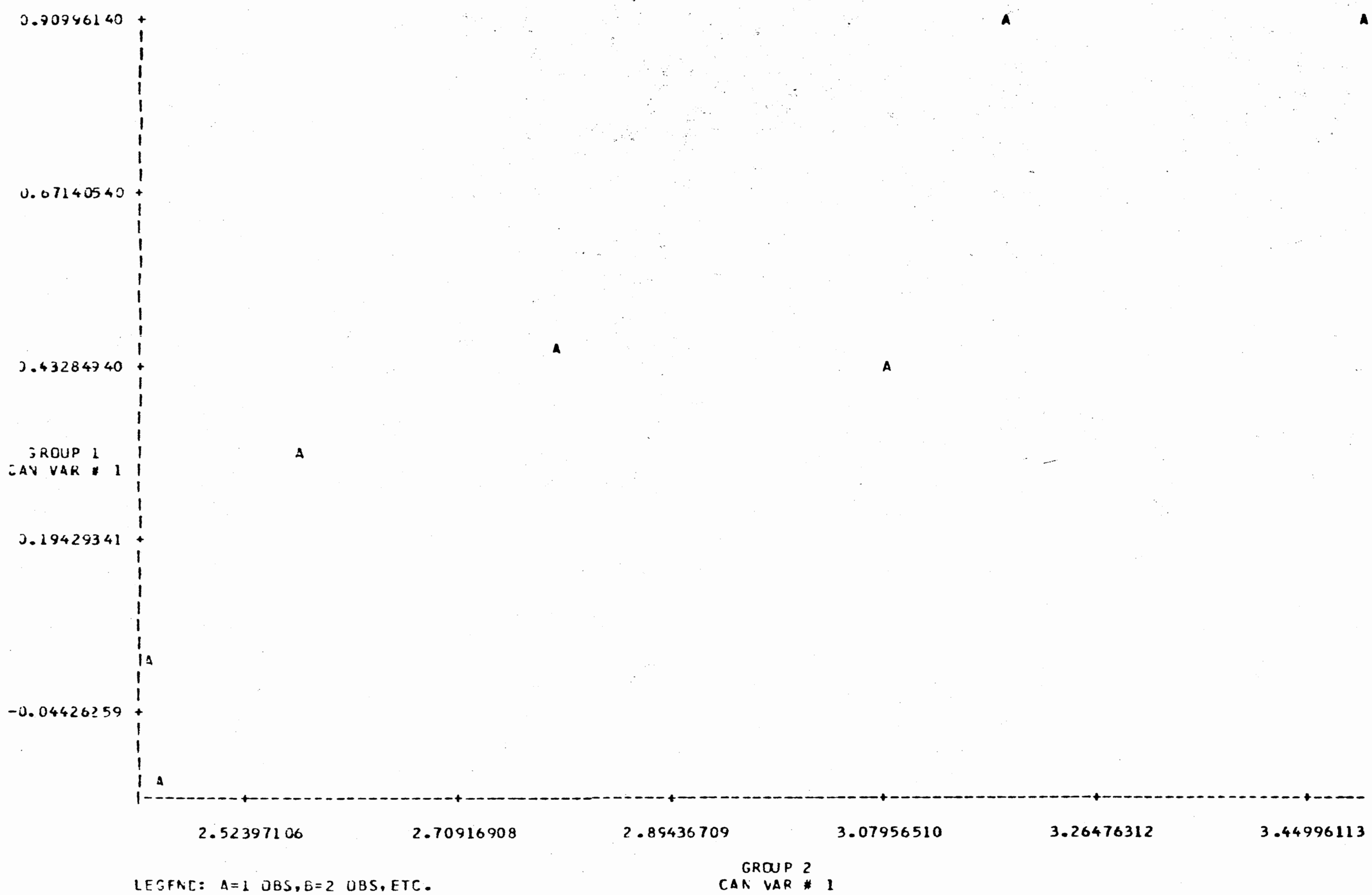


Figure 3.44. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Bt Horizons, Fifth Group, Third Set of Variables.

TABLE 3.46

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, FIRST GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.81443731	-0.49941340	0.92368591	11.86651	12	0.4567
2	-0.13098204	-3.18429420	0.23628101	0.35458	6	0.9986
3	0.77572801	6.93871594	0.04059029	0.00989	2	0.9844

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BSR	ASC	AHA
VAR # 1	0.750836	0.358421	-0.379497	0.040766
VAR # 2	-0.299373	0.871174	0.136253	0.091729
VAR # 3	0.584418	-0.115770	0.580931	-0.008509

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	OM
VAR # 1	0.579933	-0.241270	0.057608
VAR # 2	-0.783434	-0.682583	-0.940909
VAR # 3	-0.723402	0.689632	-0.333725

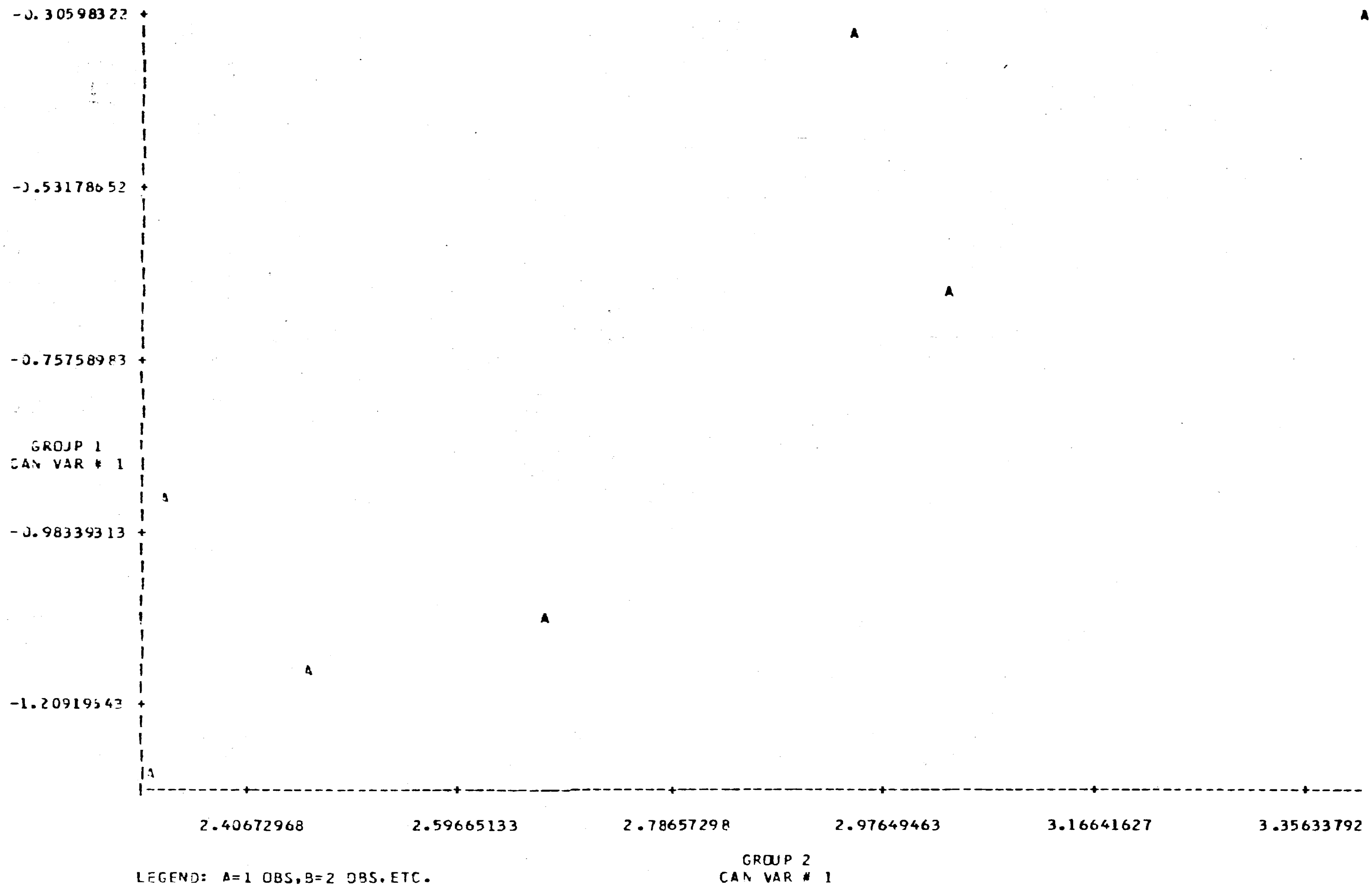


Figure 3.45. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, First Group, First Set of Variables.

TABLE 3.47

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, FIRST GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.24330616	-6.61653545	0.92474086	15.57151	12	0.2110
2	0.11560587	-1.53233844	0.62784914	3.97935	6	0.6816
3	0.90576130	3.52254450	0.38675976	0.97217	2	0.6209

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	-0.147618	0.331956	-0.450490	0.278658
VAR # 2	-0.772058	-0.260425	0.753193	-0.294514
VAR # 3	0.401133	0.483177	0.356057	0.329647

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	OM
VAR # 1	-0.323986	-0.989939	-0.517073
VAR # 2	0.945996	-0.083221	0.710655
VAR # 3	-0.011113	0.114435	-0.477080

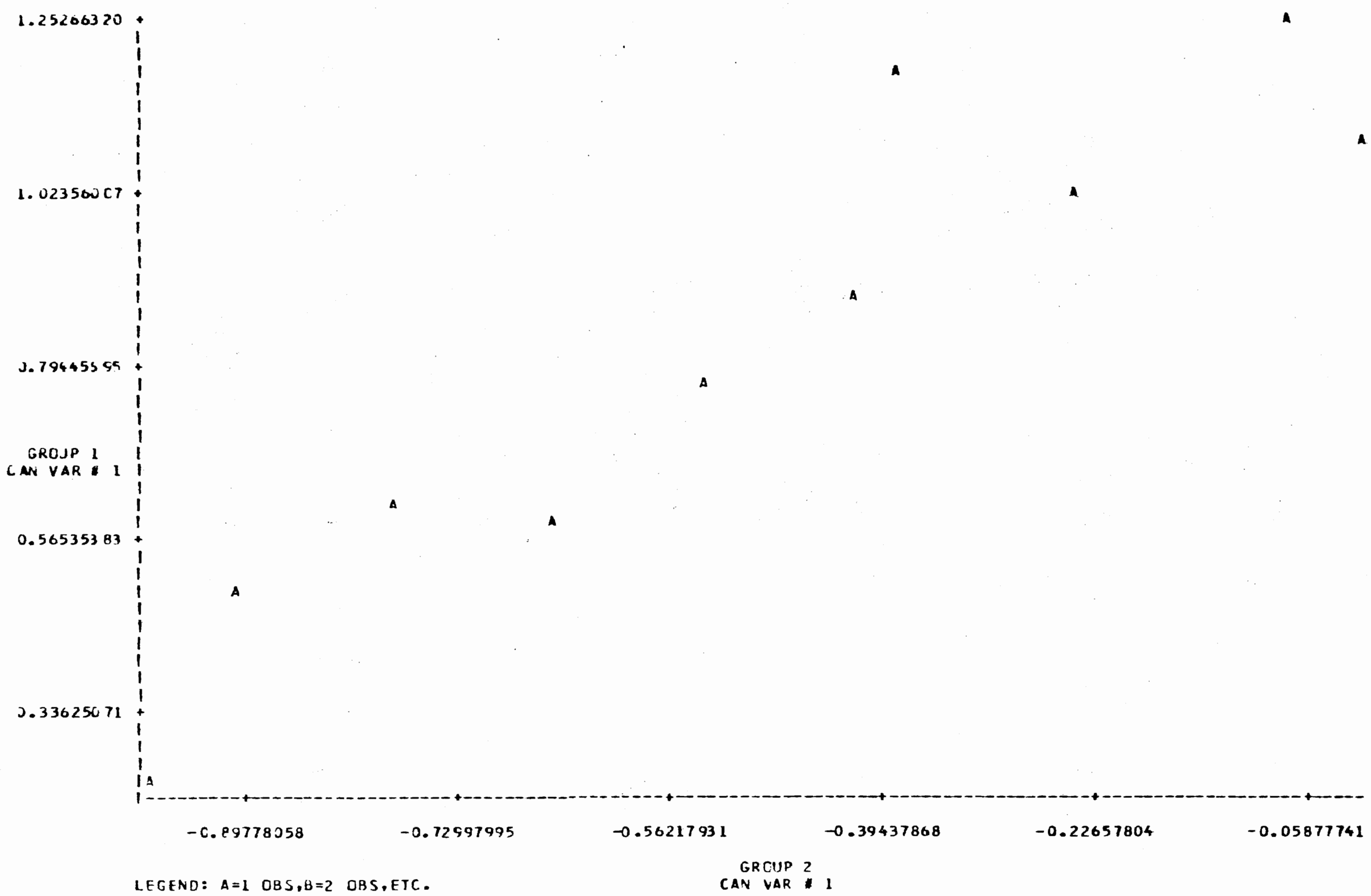


Figure 3.46. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, First Group, Second Set of Variables.

range of 8.0 with a very thick C horizon.

The Third Set of Variables. Other grasses, forbs, and shrubs with thickness, pH, and OM. The canonical correlation of the first variates of this set was .68 (Table 3.48) (Prob>Chi-SQ = .7866). This can be explained as very high other grasses values (.93) are moderately associated with very low thickness values (-.68) and high pH values (.45) (Figure 3.47). In terms of the original data, high other grasses values are favored by high pH values.

Second Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Ca, Mg, and K. The canonical correlation of the first variates of this set was .93 (Table 3.49) (Prob>Chi-SQ = .2173). This can be interpreted as high Scr values (.62), high Bgr values (.70), and moderately high Aha values (.46) are highly associated with high Mg values (.81) and moderately low K values (-.35) (Figure 3.48). In terms of the original data, high counts of Scr and Bgr are highly favored by high Mg values.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Ca, Mg, and K. The canonical correlation of the first variates of this set was .86 (Table 3.50) (Prob>Chi-SQ = .3229). This can be interpreted as high Par values (.80), high Pvi values (.65) and very low Pst values (-.82) are highly associated with high K values (.74), moderately high Mg values (.32) and moderately low Ca values (-.40) (Figure 3.49). In terms of the original data, high counts of Par and Pvi are highly associated with high values of K and Mg.

TABLE 3.48

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, FIRST GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.13758181	3.08693480	0.67999557	5.53561	9	0.7866
2	0.77744881	4.73002279	0.44817569	1.50152	4	0.8280
3	0.05643323	5.16068214	0.08221804	0.04409	1	0.8151

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.926977	0.497882	0.480185
VAR # 2	0.283134	0.852056	0.209990
VAR # 3	-0.246066	-0.161596	0.851661

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	THICK1	PH	OM
VAR # 1	-0.681220	0.450975	-0.266873
VAR # 2	0.721066	0.821233	0.835679
VAR # 3	-0.126504	0.349568	-0.480020

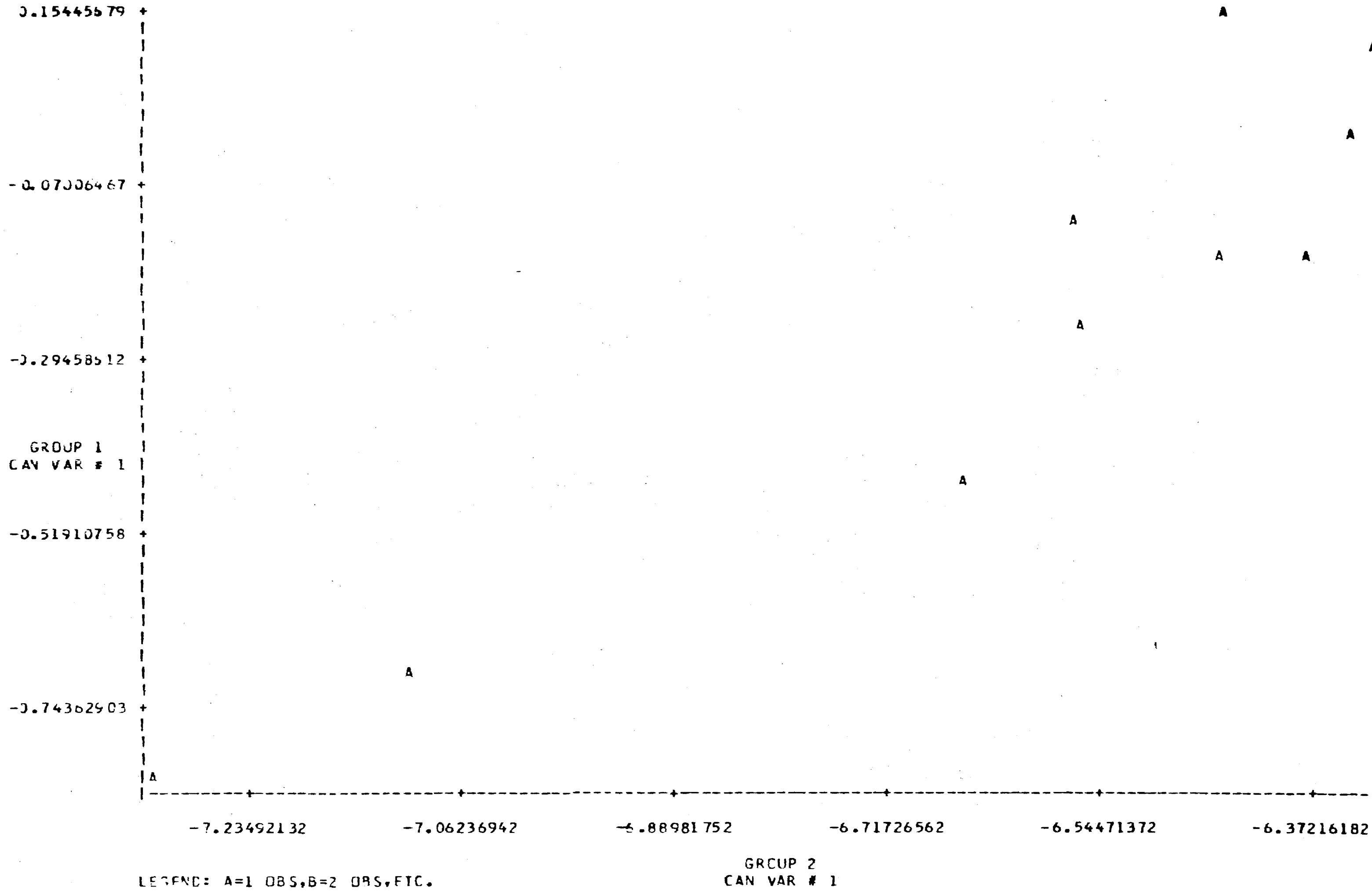


Figure 3.47. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, First Group, Third Set of Variables.

TABLE 3.49

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, SECOND GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.89456282	0.34458110	0.92583900	15.44754	12	0.2173
2	0.56717131	-2.83443374	0.66280858	3.77061	6	0.7098
3	0.45330788	-0.32751532	0.22049281	0.29903	2	0.8587

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BSR	ASC	AHA
VAR # 1	0.616197	0.698795	0.180509	0.461423
VAR # 2	0.736927	-0.644014	-0.427977	-0.440655
VAR # 3	0.269989	-0.198532	0.739562	0.067636

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	0.388741	0.807705	-0.348571
VAR # 2	-0.209573	-0.524514	-0.909554
VAR # 3	0.397195	0.269253	-0.226296

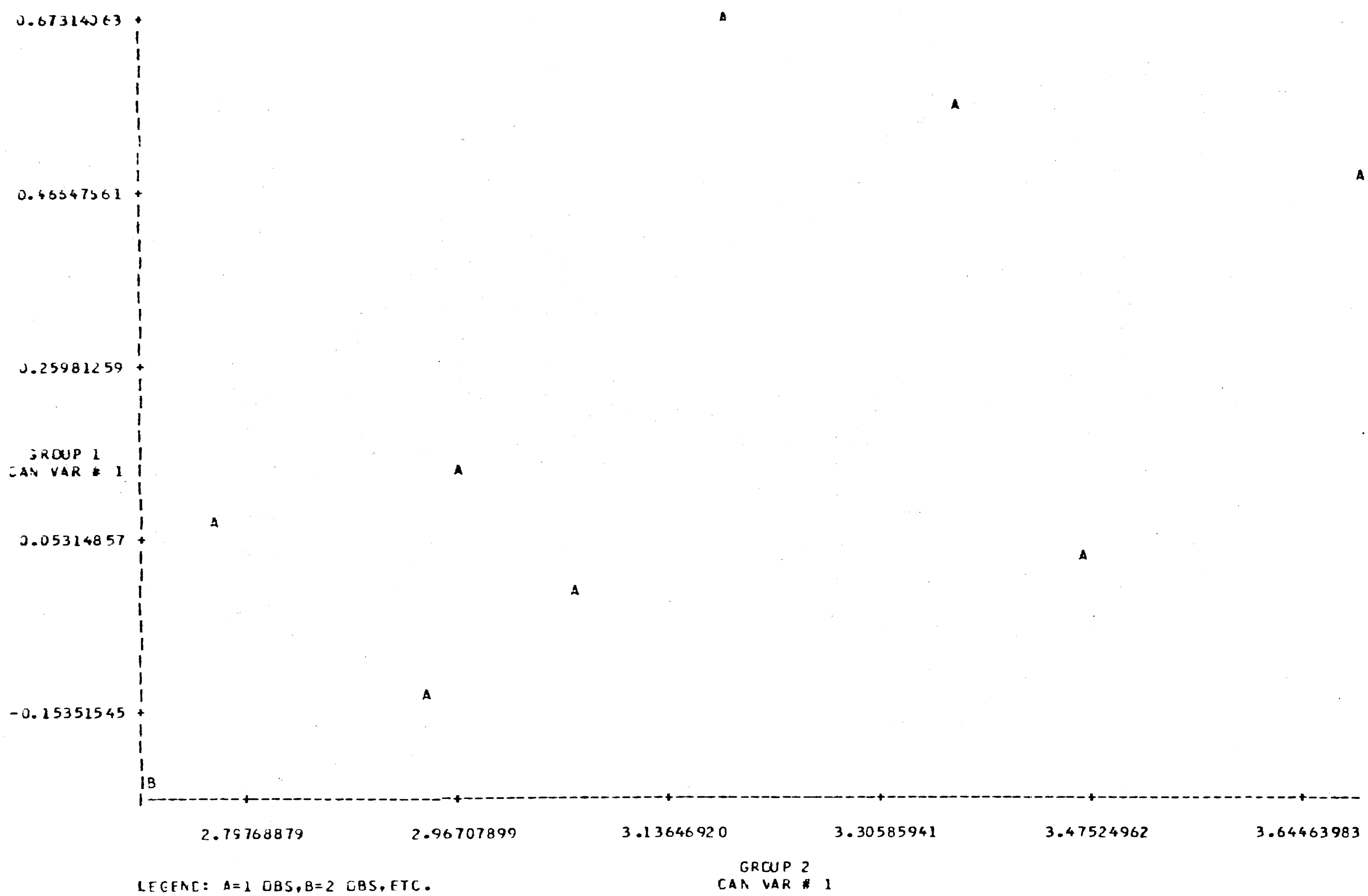


Figure 3.48. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Second Group, First Set of Variables.

TABLE 3.50

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, SECOND GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.08122333	2.29815135	0.85683866	13.65643	12	0.3229
2	-0.03020301	-1.61071937	0.77133300	5.70698	6	0.4576
3	0.63685563	-0.61575848	0.21517823	0.28445	2	0.8545

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.652476	0.104742	-0.824663	0.795198
VAR # 2	-0.363420	0.892263	0.009722	-0.538652
VAR # 3	-0.166516	0.149482	0.539900	0.267605

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	-0.399647	0.322041	0.744925
VAR # 2	-0.502186	-0.785120	-0.275351
VAR # 3	0.162303	0.529033	-0.607675

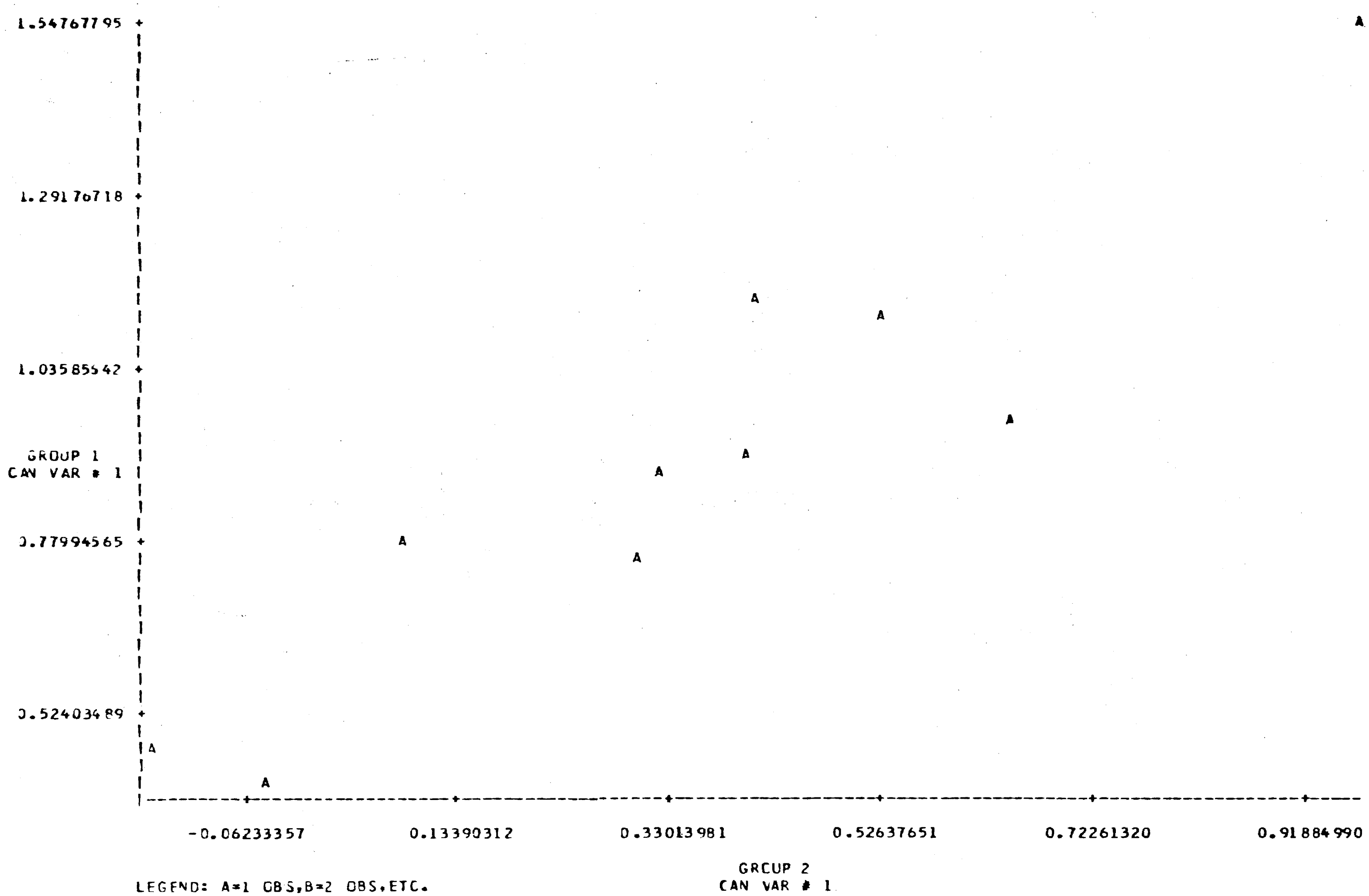


Figure 3.49. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Second Group, Second Set of Variables.

The Third Set of Variables. Other grasses, forbs, and shrubs with Ca, Mg, and K. The canonical correlation of the first variates of this set was .76 (Table 3.51) (Prob>Chi-SQ = .5887). This can be explained as moderately high forbs values (.50) are highly associated with very high Ca values (.86) and very high Mg values (.95) (Figure 3.50). In terms of the original data, high counts of forbs are favored by high values of Ca and Mg.

Third Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Na, CEC, and Clay. The canonical correlation of the first variates of this set was .90 (Table 3.52) (Prob>Chi-SQ = .2379). This can be interpreted as high Bgr values (.93), moderately high Asc values (.48), and moderately high Aha values (.60) are highly associated with high CEC values (.87) (Figure 3.51). In terms of the original data, high counts of Bgr, Asc, and Aha are favored by an increase in the CEC values.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Na, CEC, and Clay. The canonical correlation of the first variates of this set was .92 (Table 3.53) (Prob>Chi-SQ = .3848). This can be explained as very high Par values (1.0), high Pvi values (.80), and moderately low Pst values (-.52) are highly associated with high CEC values (.97), and moderately high Na values (.52) (Figure 3.52). In terms of the original data, high counts of Par and Pvi are favored by high values of CEC.

The Third Set of Variables. Other grasses, forbs, and shrubs with Na, CEC, and Clay. The canonical correlation of the first variates of this set was .88 (Table 3.54) (Prob>Chi-SQ = .0958). This can be

TABLE 3.51

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, SECOND GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.51418857	1.39503896	0.76239397	7.47723	9	0.5887
2	0.57925823	-2.30014971	0.45519440	1.81919	4	0.7716
3	0.16312614	1.00599352	0.21579969	0.30998	1	0.5848

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	-0.105768	0.498113	-0.425681
VAR # 2	0.415704	0.638814	0.894744
VAR # 3	0.903329	0.586345	-0.135012

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CA	MG	K
VAR # 1	0.858797	0.953006	0.065672
VAR # 2	0.444796	-0.233682	-0.800114
VAR # 3	0.254212	-0.192803	0.596242

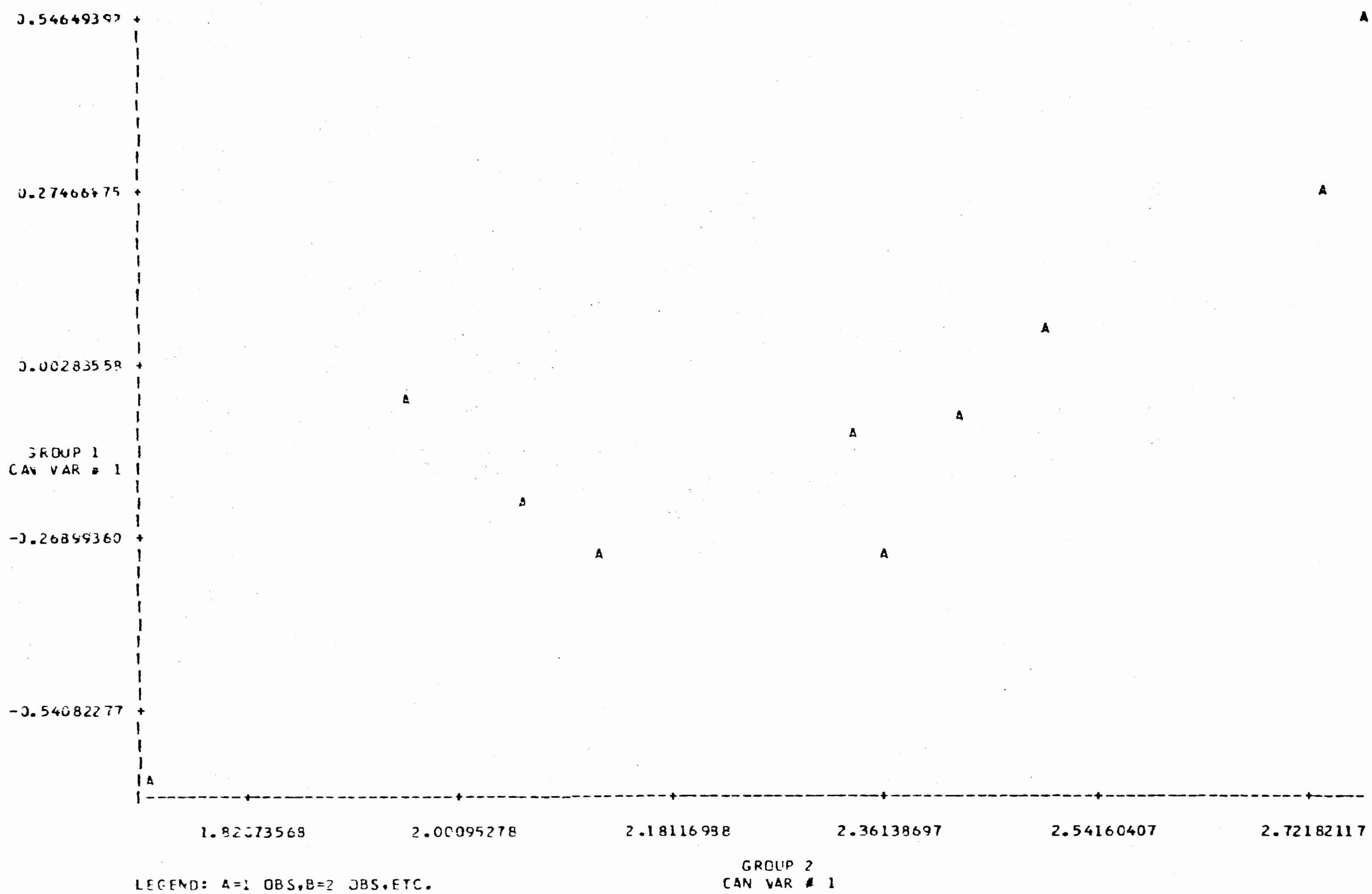


Figure 3.50. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Second Group, Third Set of Variables.

TABLE 3.52

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, THIRD GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.26831366	0.68667520	0.90156879	15.05487	12	0.2379
2	0.63368623	-1.54463925	0.74738741	5.00056	6	0.5453
3	0.91718947	1.21250183	0.12461060	0.09390	2	0.9434

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	-0.059128	0.932179	0.484671	0.590089
VAR # 2	0.444798	-0.328561	0.742168	0.202658
VAR # 3	0.866110	0.111763	-0.300849	0.050577

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	-0.175393	0.873791	-0.136801
VAR # 2	-0.982387	-0.463195	-0.350560
VAR # 3	0.064440	0.148120	0.926495

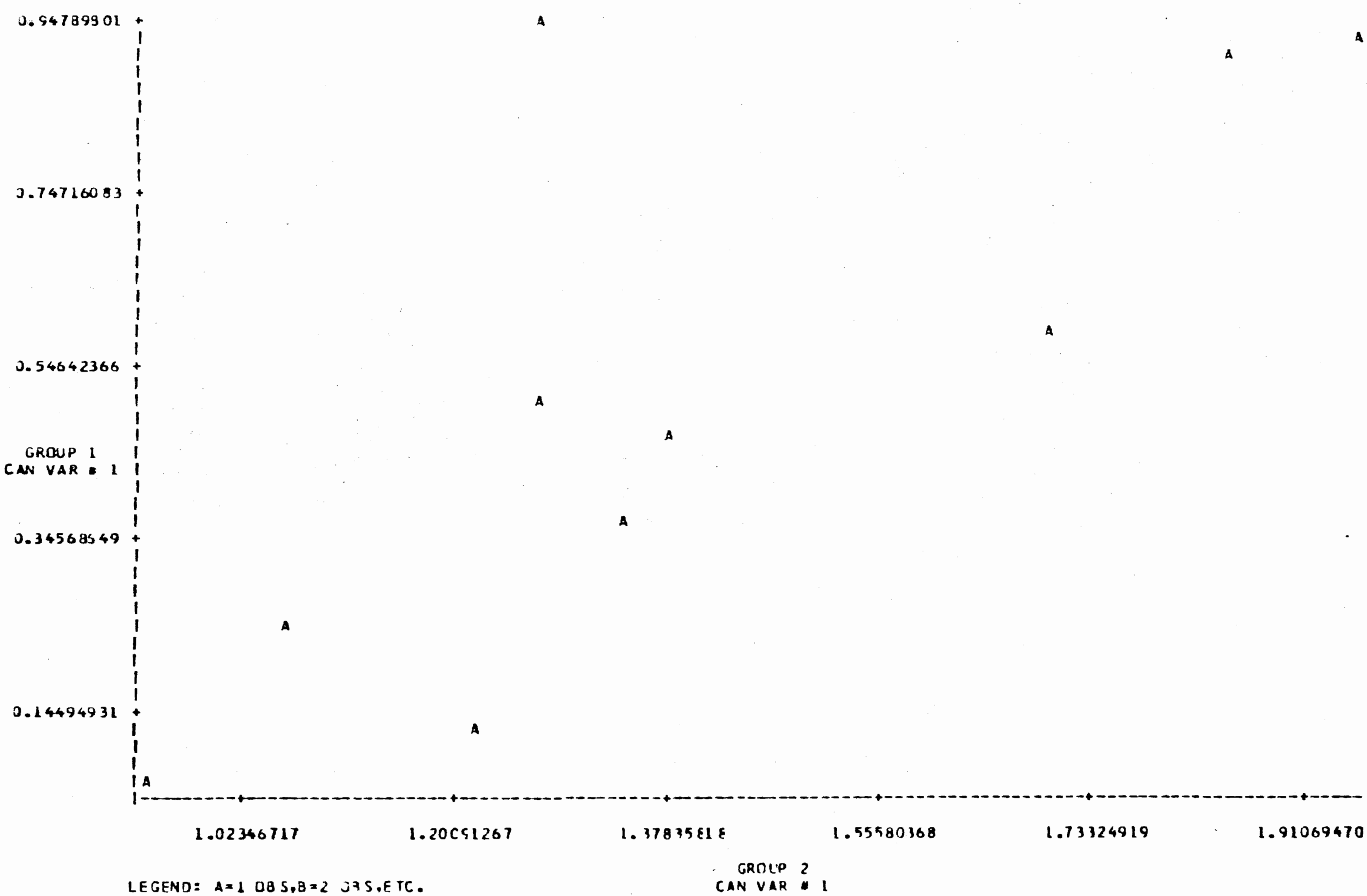


Figure 3.51. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Third Group, First Set of Variables.

TABLE 3.53

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, THIRD GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.21729049	1.57417036	0.91521045	12.79144	12	0.3843
2	0.45545125	0.18459127	0.50263558	1.88491	6	0.9294
3	0.79801865	1.34740776	0.15059399	0.13764	2	0.9247

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.804359	-0.287284	-0.515767	0.591181
VAR # 2	0.102837	0.933955	0.009759	-0.016349
VAR # 3	0.128923	-0.009008	0.774462	-0.047863

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	0.518649	0.966411	0.158775
VAR # 2	0.763793	-0.256522	-0.043520
VAR # 3	0.384217	0.015684	0.986355

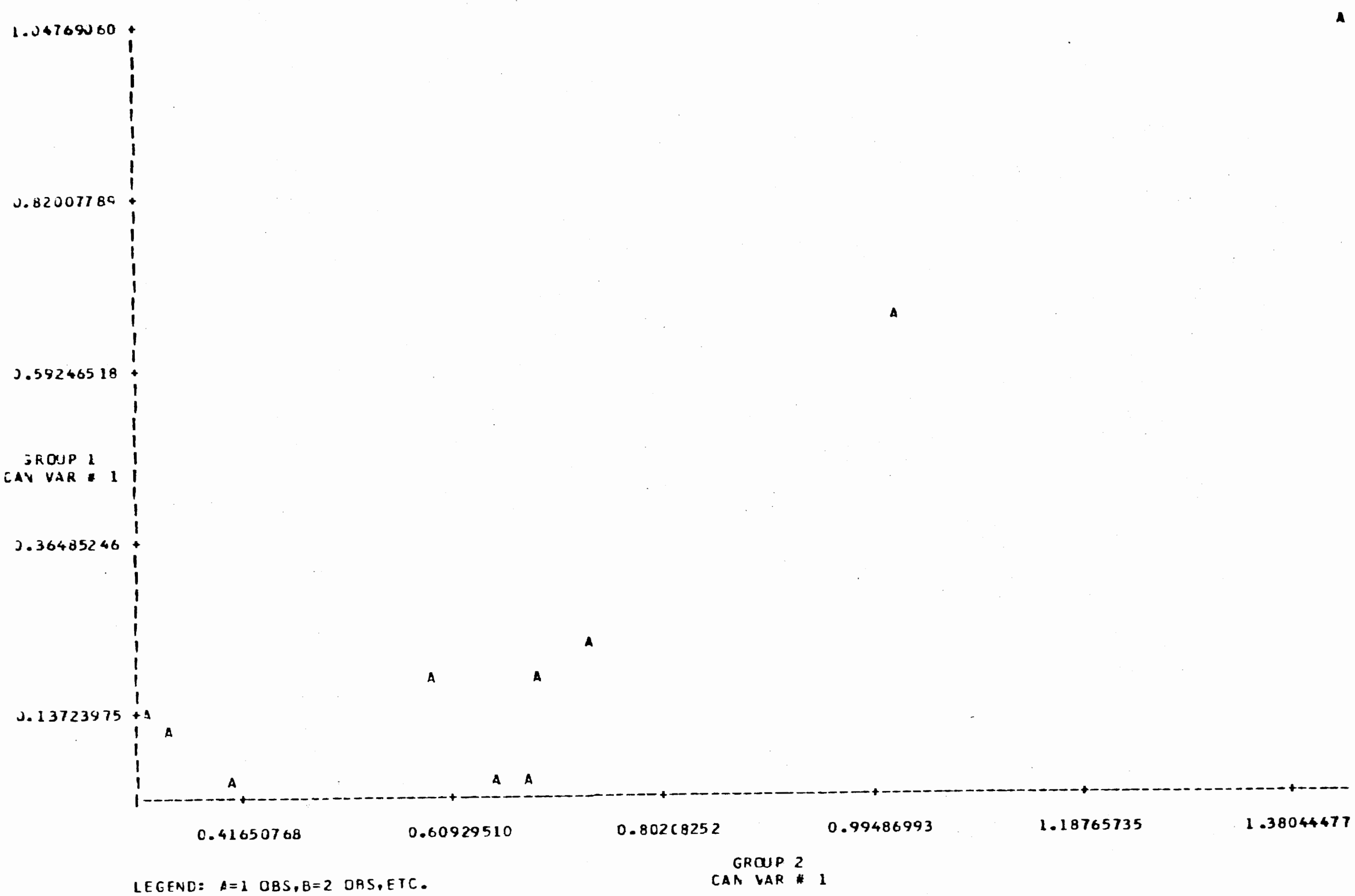


Figure 3.52. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Third Group, Second Set of Variables.

TABLE 3.54

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, THIRD GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.63624443	1.15559890	0.88494255	14.80737	9	0.0958
2	0.47071821	-1.62043203	0.71546763	4.87260	4	0.3001
3	0.01255021	0.52094207	0.17857283	0.21065	1	0.6509

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	-0.034649	0.618375	-0.181051
VAR # 2	0.772797	0.706752	0.819497
VAR # 3	-0.633707	-0.343657	0.543732

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	NA	CEC	CLAY
VAR # 1	-0.158561	0.541351	0.654642
VAR # 2	-0.971972	-0.266745	-0.623626
VAR # 3	0.173209	0.797352	-0.427240

interpreted as high forbs values (.62) are highly associated with high CEC values (.54) and high Clay values (.65) (Figure 3.53). In terms of the original data, it can be explained as high counts of forbs are highly associated with high values of CEC and Clay content.

Fourth Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was .98 (Table 3.55) (Prob>Chi-SQ = .0108). This can be interpreted as high Bgr values (.76) and moderately high Asc values (.41) are highly associated with very low Ms values (-.88) (Figure 3.54). In terms of the original data, it can be explained as low counts of Bgr and Asc are highly associated with high percentages of Ms.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was .91 (Table 3.56) (Prob>Chi-SQ = .4560). This can be interpreted as high Par values (.86), high Pvi values (.72), and low Etr values (-.67) are highly associated with very low Ms values (-.88) and very low Cs values (-.82) (Figure 3.55). In terms of the original data, the high counts of Etr seem highly associated with high percentages of Ms and Cs.

The Third Set of Variables. Other grasses, forbs and shrubs with Vcs, Cs, and Ms. The canonical correlation of the first variates of this set was .93 (Table 3.57) (Prob>Chi-SQ = .1149). This can be interpreted as moderately high forbs values (.53) and moderately low shrubs values (-.38) are highly associated with high Vcs values (.66) and very low Ms values (0.72) (Figure 3.56). In terms of the original data, it

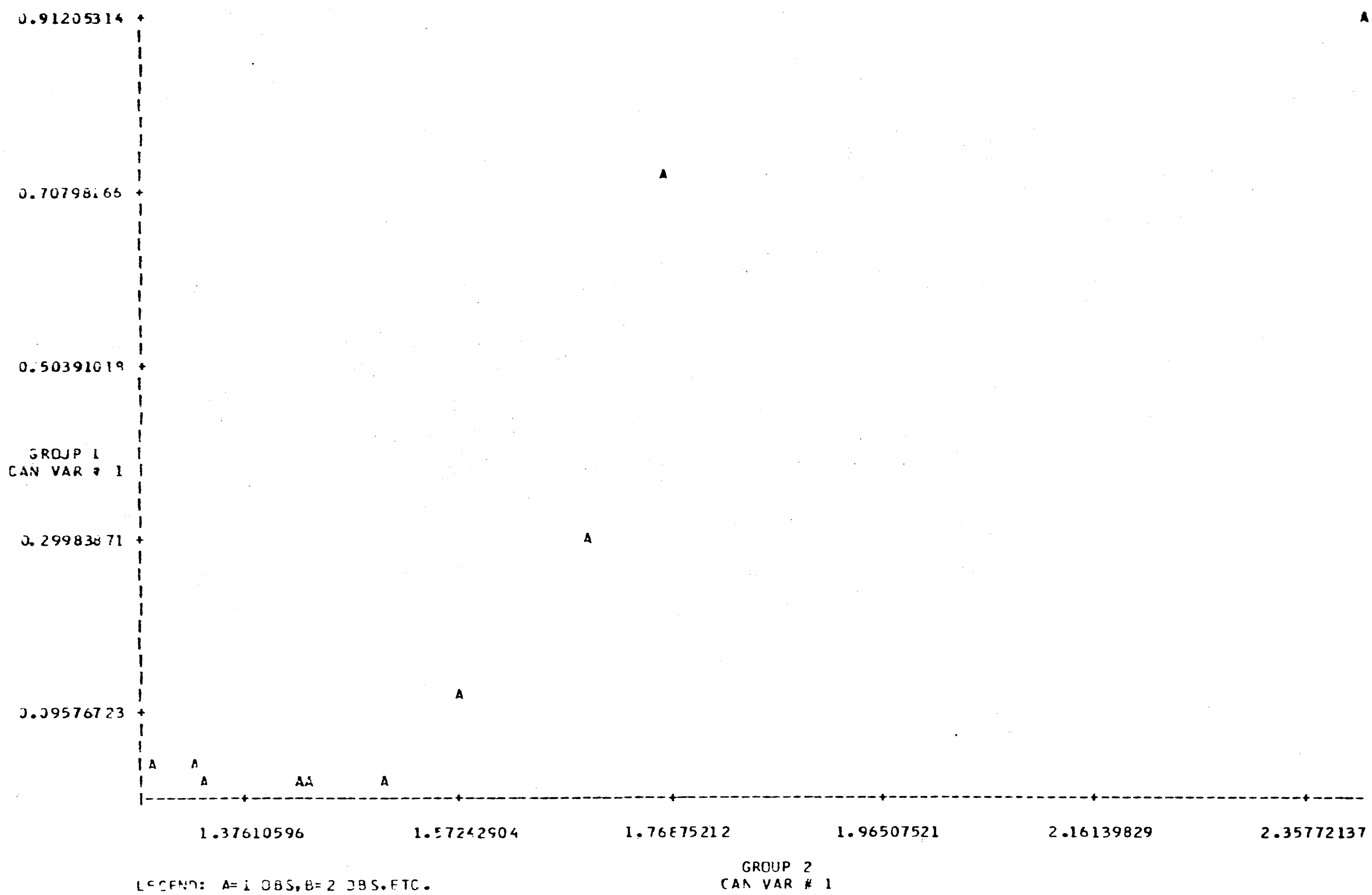


Figure 3.53. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Third Group, Third Set of Variables.

TABLE 3.55

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS
FOURTH GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.64586779	-1.43829019	0.97923833	25.99621	12	0.0108
2	0.75348841	0.64765702	0.82133431	6.84460	6	0.3352
3	0.46378319	0.10138175	0.13392231	0.10859	2	0.9371

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCS	BGR	ASC	AHA
VAR # 1	0.345313	0.757901	0.408356	0.241863
VAR # 2	0.740411	-0.613362	0.217253	-0.199007
VAR # 3	0.262146	0.187050	0.325060	0.838774

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	DS	MS
VAR # 1	0.944632	0.026706	-0.876007
VAR # 2	0.613366	0.932552	0.416048
VAR # 3	0.788537	-0.360045	-0.243959

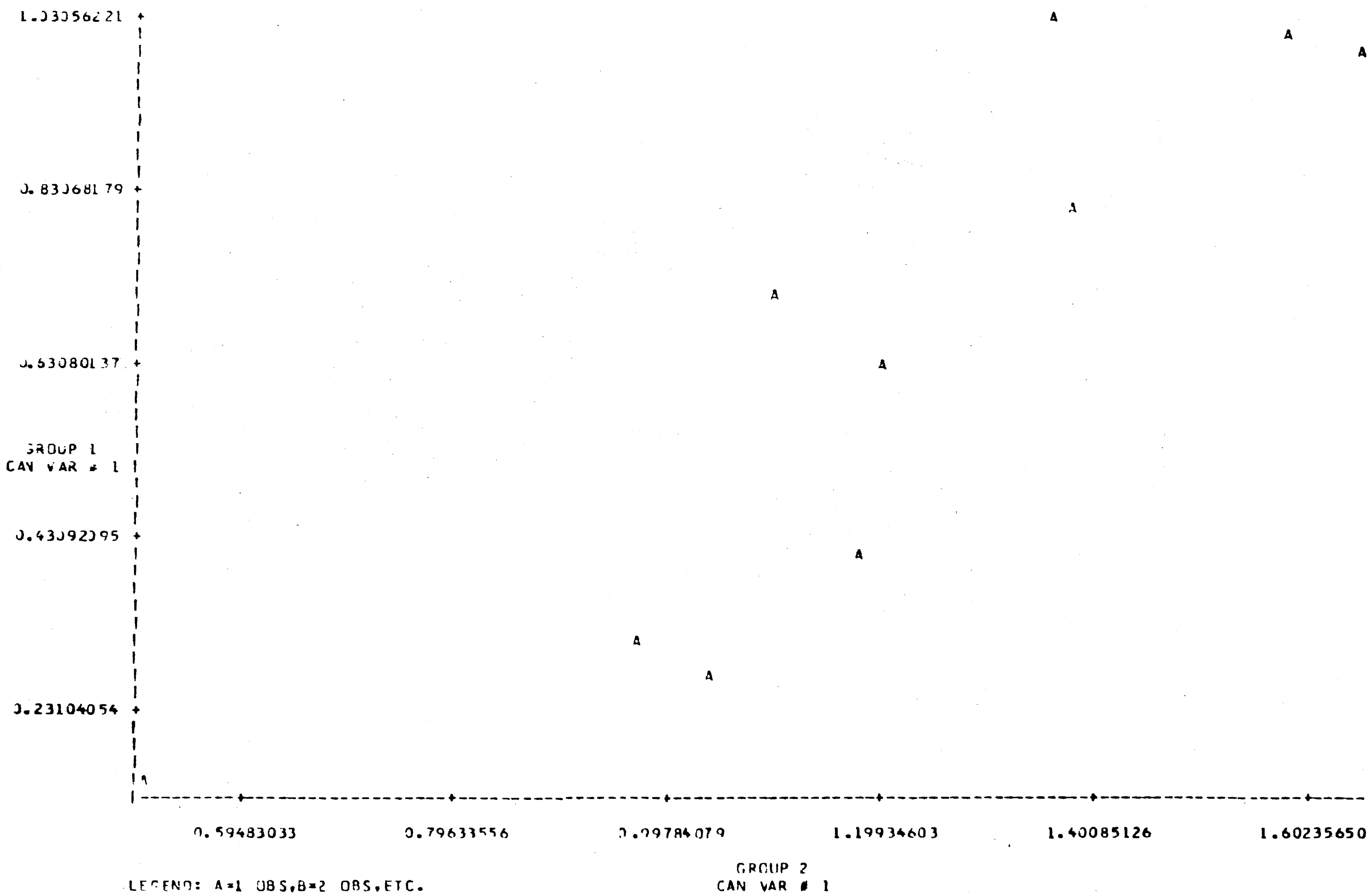


Figure 3.54. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Fourth Group, First Set of Variables.

TABLE 3.56

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, FOURTH GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.04304525	-1.27471055	0.91491785	11.87474	12	0.4560
2	-0.40365124	-0.93440461	0.36902071	0.98796	6	0.9844
3	0.59851476	0.02043489	0.13456552	0.10964	2	0.9366

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.718391	-0.669179	-0.421525	0.860581
VAR # 2	-0.374005	-0.154073	-0.292278	0.288384
VAR # 3	-0.311298	-0.191077	0.848232	-0.001398

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	-0.242961	-0.819349	-0.877192
VAR # 2	-0.089423	0.554720	-0.418778
VAR # 3	0.965905	0.144749	-0.234858

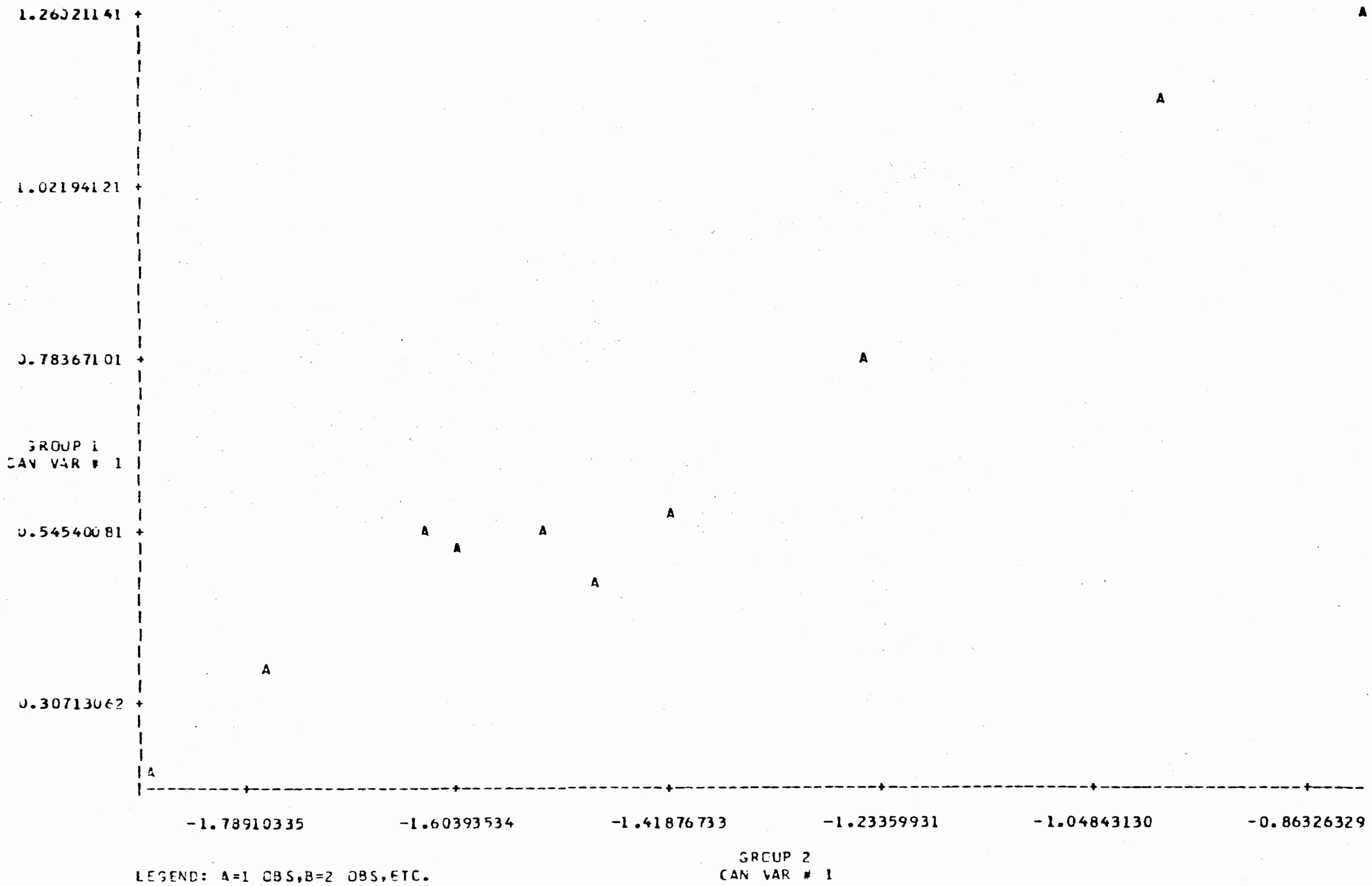


Figure 3.55. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Fourth Group, Second Set of Variables.

TABLE 3.57

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, FOURTH GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.54254949	-0.76699831	0.93243943	14.19541	9	0.1149
2	0.57254453	-0.92317153	0.35985981	0.96175	4	0.9145
3	0.06612808	1.02853511	0.09608819	0.06029	1	0.7933

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	-0.090020	0.526766	-0.377604
VAR # 2	0.744651	0.795980	0.785703
VAR # 3	-0.661356	-0.298216	0.489985

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	VCS	CS	MS
VAR # 1	0.655640	-0.294171	-0.716012
VAR # 2	-0.173303	0.545600	-0.389779
VAR # 3	0.734917	0.784719	0.579137

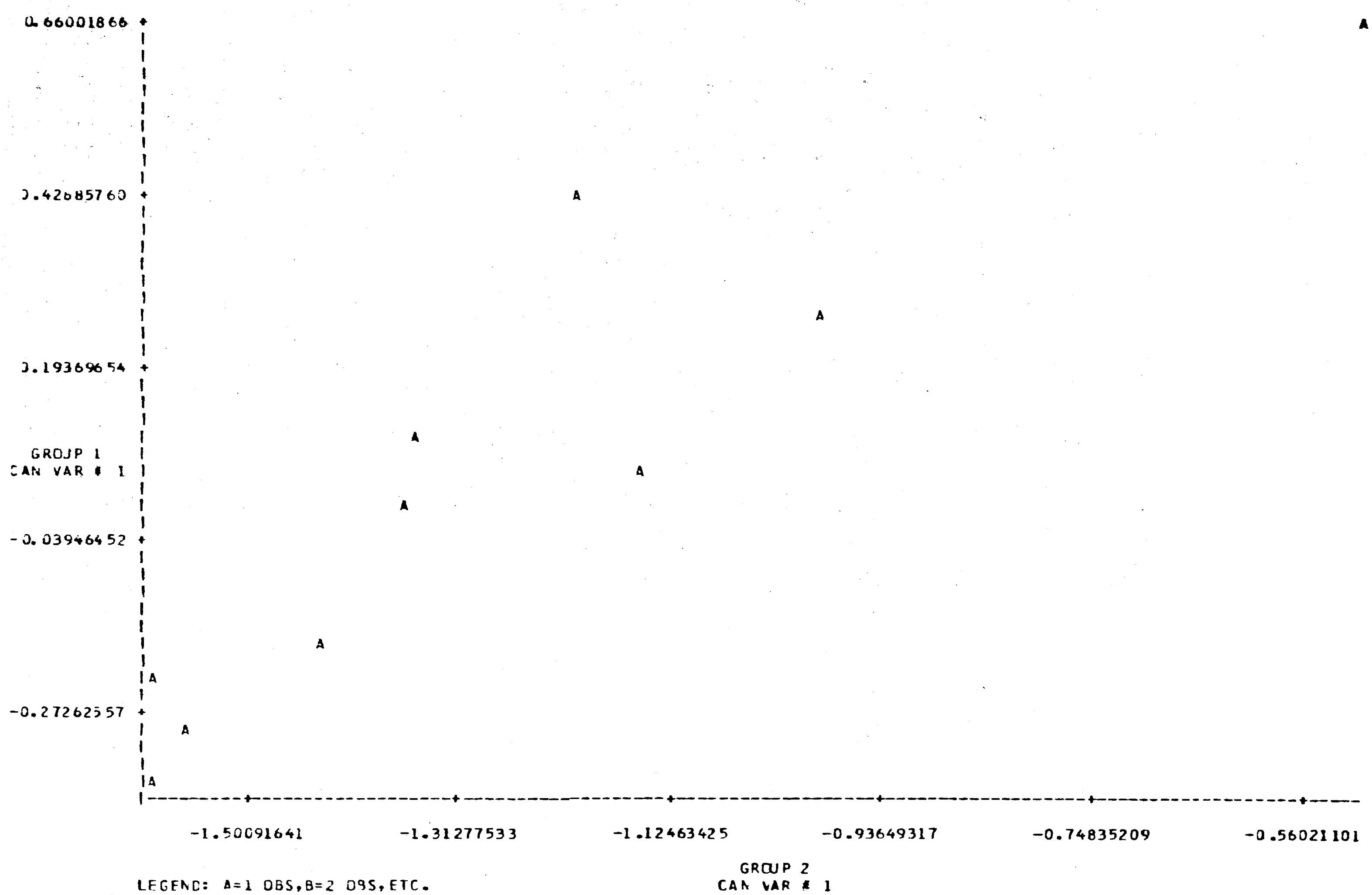


Figure 3.56. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Fourth Group, Third Set of Variables.

can be explained as high counts of shrubs are highly associated with high percentages of Ms, while high counts of forbs are highly associated with high percentages of Vcs and Cs.

Fifth Group

The First Set of Variables. Scr, Bgr, Asc, and Aha with Fs and Vfs. The canonical correlation of the first variates of this set was .87 (Table 3.58) (Prob>Chi-SQ = .0603). This can be explained as high Bgr values (.78) and moderately high Asc values (.38) are highly associated with very high Fs values (.98) and high Vfs values (.64) (Figure 3.57). In terms of the original data, it can be explained as high counts of Bgr and Asc are highly associated with high percentages of Fs and Vfs.

The Second Set of Variables. Pvi, Etr, Pst, and Par with Fs and Vfs. The canonical correlation of the first variates of this set was .88 (Table 3.59) (Prob>Chi-SQ = .1390). This can be interpreted as high Pvi values (.79), high Par values (.81), and low Etr values (-.62) are highly associated with high Fs values (.86) and very high Vfs values (1.0) (Figure 3.58). In terms of the original data, it can be explained as high counts of Pvi and Par with low counts of Etr are highly associated with high percentages of Fs and Vfs.

The Third Set of Variables. Other grasses, forbs, and shrubs with Fs and Vfs. The canonical correlation of the first variates of this set was .82 (Table 3.60) (Prob>Chi-SQ = .2416). This can be explained as high forbs values (.69) are highly associated with very high Fs values (.92), and high Vfs values (.52) (Figure 3.59). In terms of the original data, it can be explained as high counts of forbs are favored

TABLE 3.58

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, FIFTH GROUP, FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.56509459	1.75427879	0.86591904	14.92182	8	0.0503
2	0.65128176	0.31960543	0.77299342	5.91570	3	0.1140

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA
VAR # 1	0.276712	0.779650	0.384319	0.208121
VAR # 2	0.7[illegible]8302	-0.585339	0.006509	-0.491192

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	0.976353	0.635133
VAR # 2	-0.216182	-0.772403

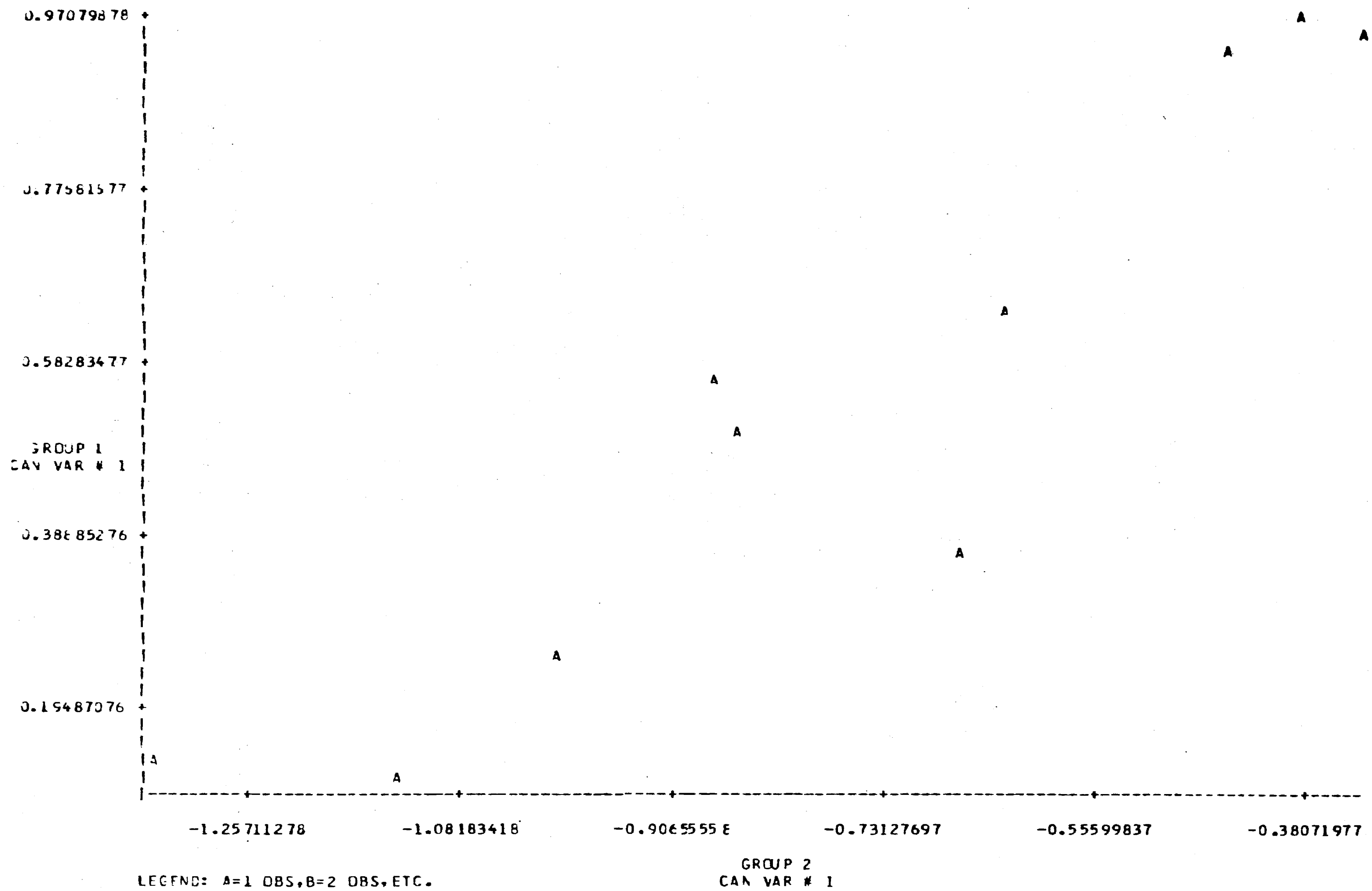


Figure 3.57. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Fifth Group, First Set of Variables.

TABLE 3.59

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, FIFTH GROUP, SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.05096130	1.07323263	0.87843870	12.26444	8	0.1390
2	-0.06113677	-1.42401314	0.57992343	2.66462	3	0.4484

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	PVI	ETR	PST	PAR
VAR # 1	0.787102	-0.621811	-0.445912	0.812518
VAR # 2	0.520297	0.587458	-0.550199	-0.060806

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	0.864400	0.990511
VAR # 2	-0.502804	0.137437

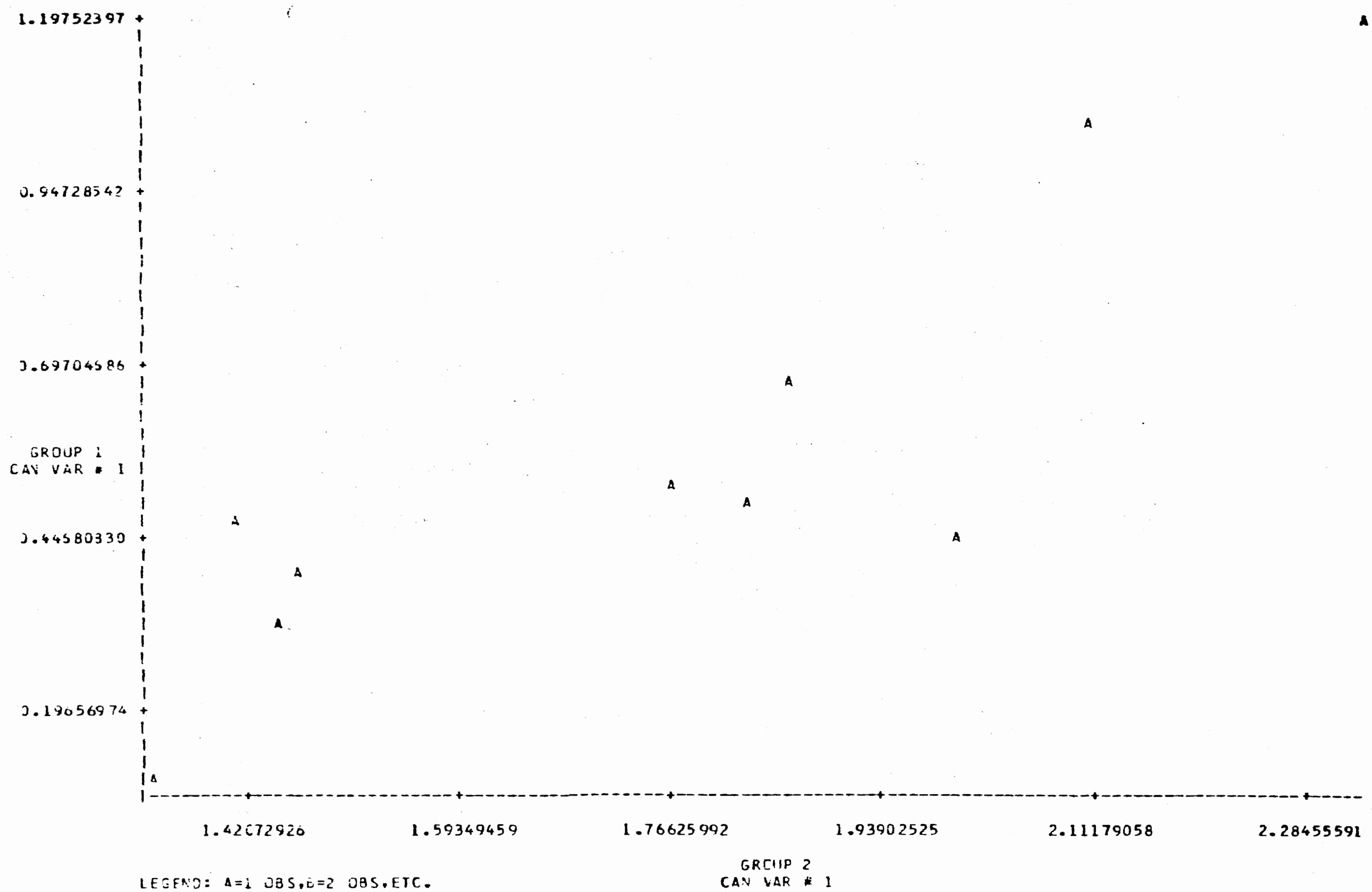


Figure 3.58. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Fifth Group, Second Set of Variables.

TABLE 3.60

CANONICAL CORRELATION ANALYSIS FOR C HORIZONS, FIFTH GROUP, THIRD SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.62189615	1.78205411	0.82043133	7.94092	6	0.2415
2	0.47571622	-0.06264876	0.12712801	0.11405	2	0.9347

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	OTHER	FORBS	SHRUBS
VAR # 1	0.131790	0.694341	-0.293725
VAR # 2	0.700505	0.672279	0.870906

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	FS	VFS
VAR # 1	0.934946	0.516803
VAR # 2	0.355054	0.856104

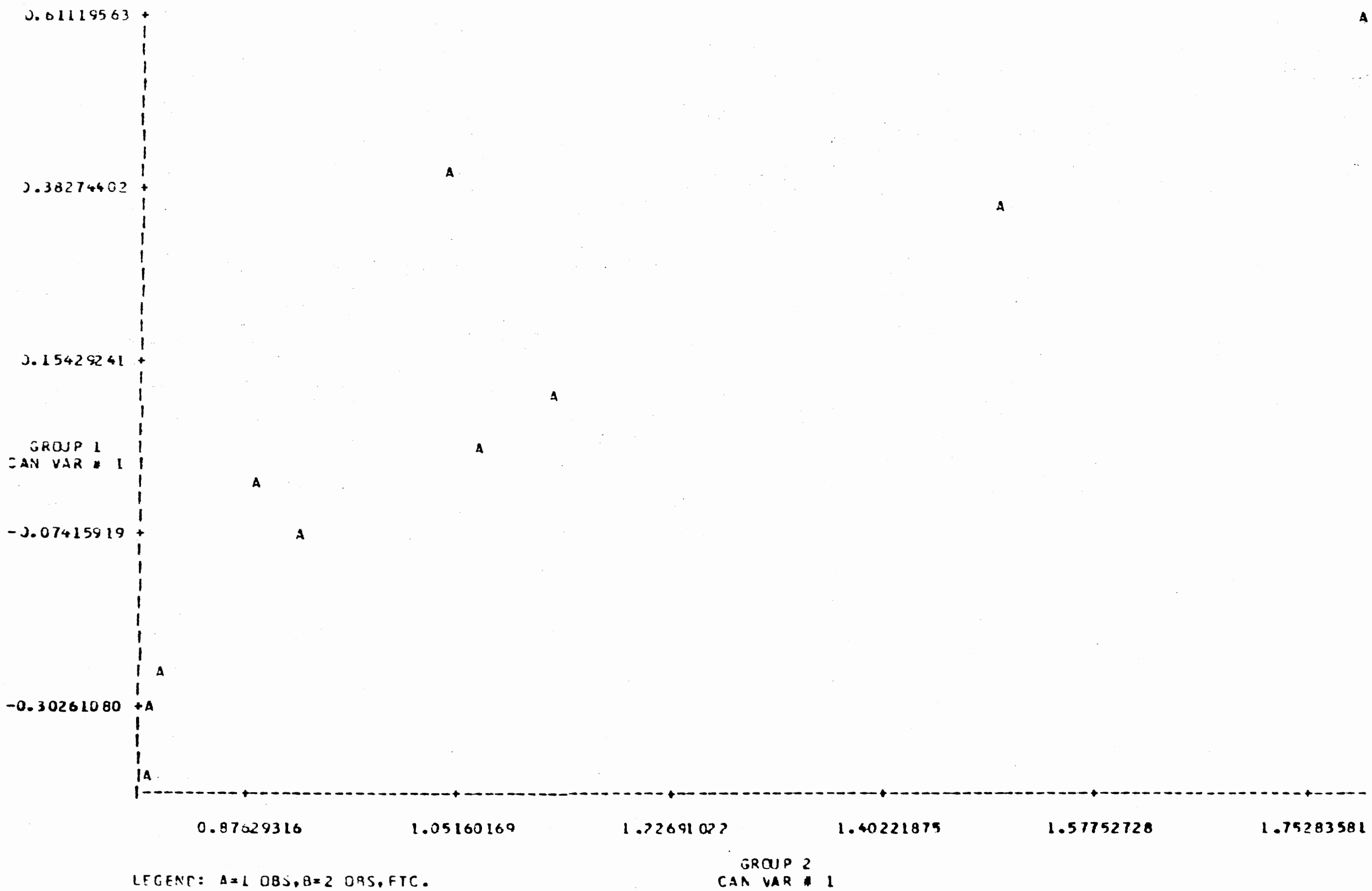


Figure 3.59. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for C Horizons, Fifth Group, Third Set of Variables.

by high percentages of Fs and Vfs.

Canonical Correlation Using Temperature Readings at 15 cm Depth

The vegetation variables are Scr, Bgr, Asc, Aha, and Pvi with the temperature readings of May, June, July, August, September, October, and November. The canonical correlation of the first variates was 1.0 (Table 3.61) (Prob>Chi-SQ = .0001), which can be explained as high counts of Scr (.65) and very low counts of Aha (-.84) are highly associated with high May through October temperatures and low November temperature readings (Figure 3.60). The Bgr, Asc, and Pvi are too small to be listed. In terms of the original data, the highest Scr counts per 2 m^2 exists on the 23E position (18.5) and Aha in this position is .1. The highest temperature value was recorded in 11W (27.7^{o}C). The differences in temperature between the different locations is not significant.

The other group of vegetation variables are Etr, Pst, Par, other grasses, and forbs with temperatures of May through November at 15 cm depth. The canonical correlation of the first variates was 1.0 (Table 3.62) (Prob>Chi-SQ = .0001). This can be interpreted as high Etr values (.65), low values of other grasses (-.57), and low forbs values (-.53) are highly associated with low values of May through September and moderately high values of October and November. In another way, the high counts of other grasses and forbs are highly associated with high temperature readings of May through September (Figure 3.61).

TABLE 3.61

CANONICAL CORRELATION ANALYSIS FOR TEMPERATURE AT 15 CM DEPTH WITH THE FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.20805886	0.56654448	1.00000000	184.11610	35	0.0001
2	0.80399190	7.70442603	0.99026445	33.86970	24	0.0868
3	0.49557425	-9.87474715	0.90176273	12.17933	15	0.6662
4	0.76074370	-15.36199929	0.60396614	2.95259	8	0.9369
5	0.50293553	8.63097374	0.28231637	0.45682	3	0.9251

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA	PVI
VAR # 1	0.654423	0.171485	-0.247226	-0.842006	-0.248120
VAR # 2	0.619067	-0.325029	-0.402405	-0.359107	-0.122824
VAR # 3	-0.172892	0.725542	0.440798	-0.078227	0.710933
VAR # 4	0.198260	-0.234585	0.643486	0.164517	0.250130
VAR # 5	0.371405	0.532455	-0.410587	0.359002	-0.596120

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	MAY15	JUNE15	JULY15	AUG15	SEPT15	OCT15	NOV15
VAR # 1	0.875462	0.512666	0.693016	0.496730	0.688208	0.599398	-0.428046
VAR # 2	0.368881	-0.542533	0.257205	0.443068	0.463827	-0.210686	-0.662419
VAR # 3	0.170935	0.205034	-0.135738	0.358932	0.024428	-0.509340	-0.155562
VAR # 4	-0.192151	-0.535468	-0.194980	-0.229647	-0.291758	-0.358533	0.021548
VAR # 5	0.158999	-0.029734	-0.059066	0.506276	0.211296	0.422421	0.448794

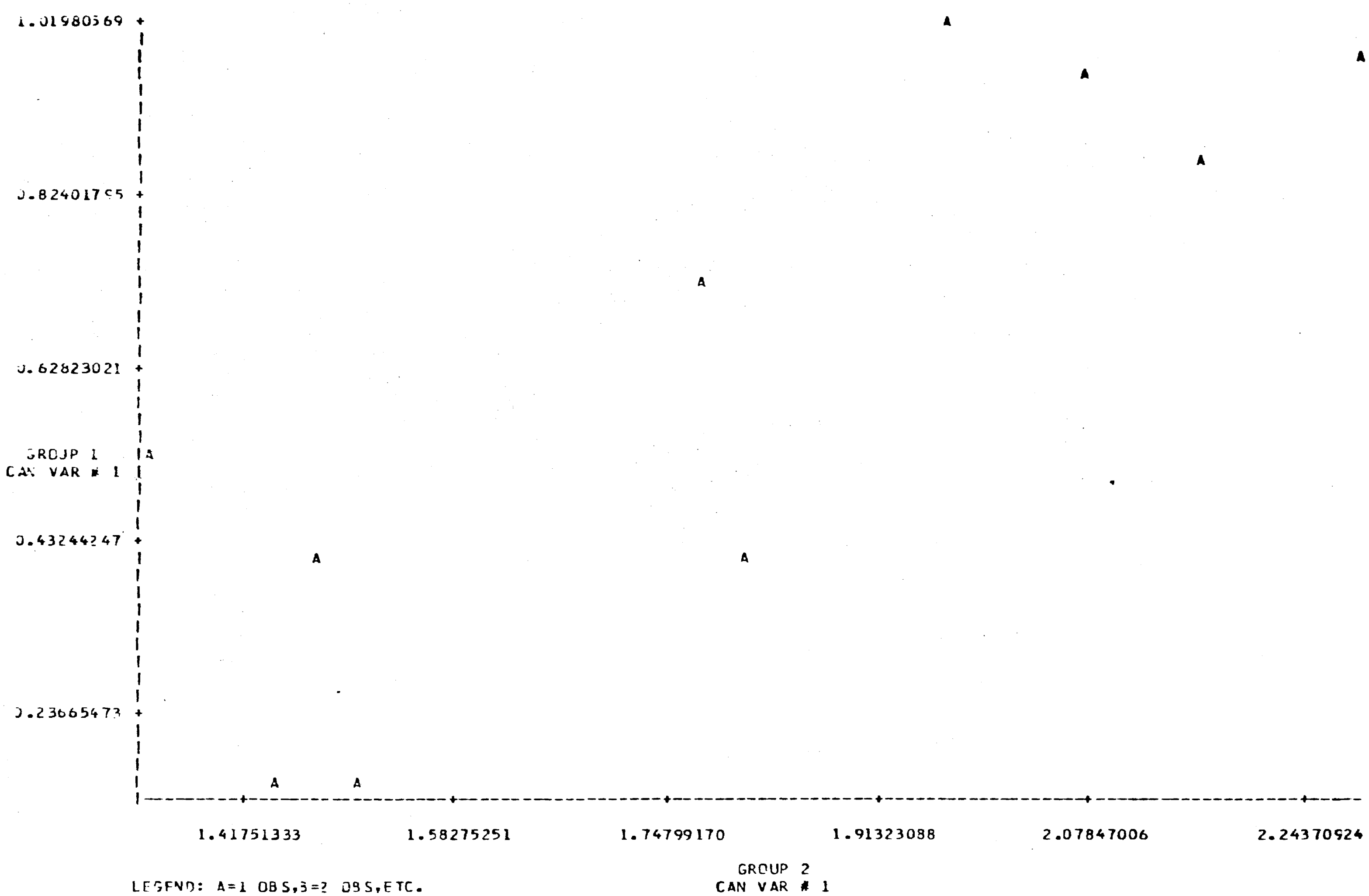


Figure 3.60. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Temperature at 15 cm Depth with the First Set of Variables.

TABLE 3.62

CANONICAL CORRELATION ANALYSIS FOR TEMPERATURE AT
15 CM DEPTH WITH THE SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.73071405	15.80855928	1.00000000	184.91753	35	0.0001
2	0.82319436	0.35340535	0.99466048	40.76615	24	0.0177
3	0.10103948	0.04643858	0.93722930	15.78435	15	0.3965
4	0.37686609	7.84837515	0.67219514	4.19581	8	0.8400
5	0.92320595	8.08833738	0.38637003	0.88921	3	0.8295

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	ETR	PST	PAR	OTHER	FORBS
VAR # 1	0.650935	-0.167636	-0.395438	-0.570412	-0.525391
VAR # 2	0.316529	0.303519	0.404327	-0.635437	-0.072809
VAR # 3	0.065320	0.934161	-0.642700	-0.038771	-0.159663
VAR # 4	-0.148704	-0.084250	-0.466973	0.438852	0.826595
VAR # 5	0.670206	-0.004332	-0.221408	0.277050	0.099559

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	MAY15	JUNE15	JULY15	AUG15	SEPT15	OCT15	NOV15
VAR # 1	-0.327775	-0.470485	-0.397362	-0.011696	-0.152545	0.145138	0.511505
VAR # 2	0.246940	-0.303462	0.184984	0.493463	0.338369	-0.599369	-0.509210
VAR # 3	0.267828	-0.449758	0.432068	0.045711	0.333957	0.220114	-0.536104
VAR # 4	-0.274199	-0.061893	-0.205400	-0.587398	-0.291337	-0.132191	0.181274
VAR # 5	0.377506	0.034180	-0.071449	0.177019	0.197355	0.117593	-0.266810

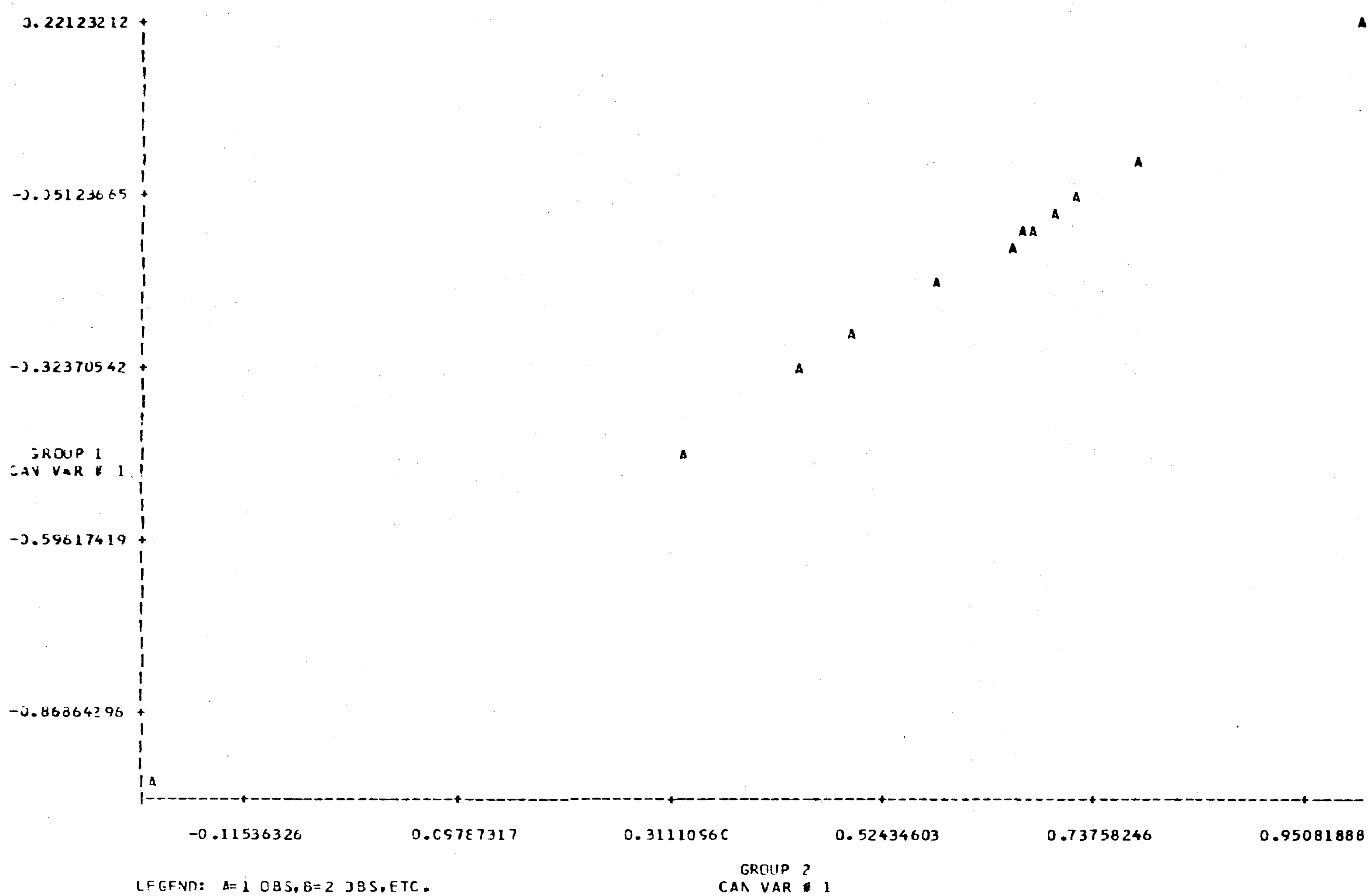


Figure 3.61. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Temperature at 15 cm Depth with the Second Set of Variables.

Canonical Correlation Using Temperature Readings at 50 cm Depth

The vegetation variables are Scr, Bgr, Asc, Aha, and Pvi with the temperature readings in May, June, July, August, September, October, and November at 50 cm depth. The canonical correlation of the first variates was 1.0 (Table 3.63) (Prob>Chi-SQ = .0001). Low Scr values (-.40), low Bgr values (-.52), and high Aha values (.79) are highly associated with low temperature values for May (-.55), June (-.65), and July (-.55), high values for August (.60), low values for September (-.65) and October (-.67), and high values for November (.09) (Figure 3.62). In another way, high counts of Scr, high counts of Bgr, and low counts of Aha are correlated with high temperatures from May through October, and low temperatures for November. August has a low temperature in 13E and 24E (24.1 and 24.2^{o}C, respectively).

The other group of vegetation variables are Etr, Pst, Par, other grasses, and forbs. The canonical correlation of the first variates was 1.0 (Table 3.64) (Prob>Chi-SQ = .0001). This could be explained as low Etr (-.44), low Pst (-.35), and high Par (.97) are highly associated with low (-ev/y) value of temperature from June through October and high (+ev/y) value for November (.59), which means high Etr counts, high Pst counts with low Par counts are highly corresponding with relatively high temperature values from May through October and with low November temperature value (Figure 3.63).

Canonical Correlation Using Total Moisture Content

The vegetation variables are Scr, Bgr, Asc, Aha, and Pvi with the

TABLE 3.63

CANONICAL CORRELATION ANALYSIS FOR TEMPERATURE AT 50 CM DEPTH WITH THE FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.16778251	0.84534280	1.00000000	193.07250	35	0.0001
2	0.31795924	-14.70662349	0.98174187	33.25407	24	0.0986
3	0.04049951	12.67589296	0.90941520	14.99865	15	0.4517
4	1.12430695	8.51756622	0.63488464	5.34795	8	0.7214
5	0.61016595	13.38767717	0.60533476	2.51012	3	0.4760

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCP	BGR	ASC	AHA	PVI
VAR # 1	-0.401696	-0.521547	0.097600	0.797704	-0.126725
VAR # 2	-0.350792	-0.145065	0.588761	-0.088298	0.893193
VAR # 3	-0.525564	0.807664	0.327103	0.591121	0.308961
VAR # 4	0.625603	0.233231	-0.340737	-0.020998	-0.195095
VAR # 5	0.709206	-0.015064	0.648642	0.077504	0.229411

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	MAY50	JUNE50	JULY50	AUG50	SEPT50	OCT50	NOV50
VAR # 1	-0.550500	-0.519555	-0.545522	0.590117	-0.646353	-0.665480	0.094039
VAR # 2	-0.463317	-0.288034	-0.376639	-0.567917	-0.318355	-0.668153	-0.133503
VAR # 3	-0.273980	-0.542712	-0.473598	-0.480779	-0.399524	-0.211645	0.906200
VAR # 4	0.315571	0.152069	0.360148	0.022868	0.435254	0.136924	-0.053466
VAR # 5	-0.387060	-0.232907	0.021436	0.033126	-0.077376	0.059576	-0.035206

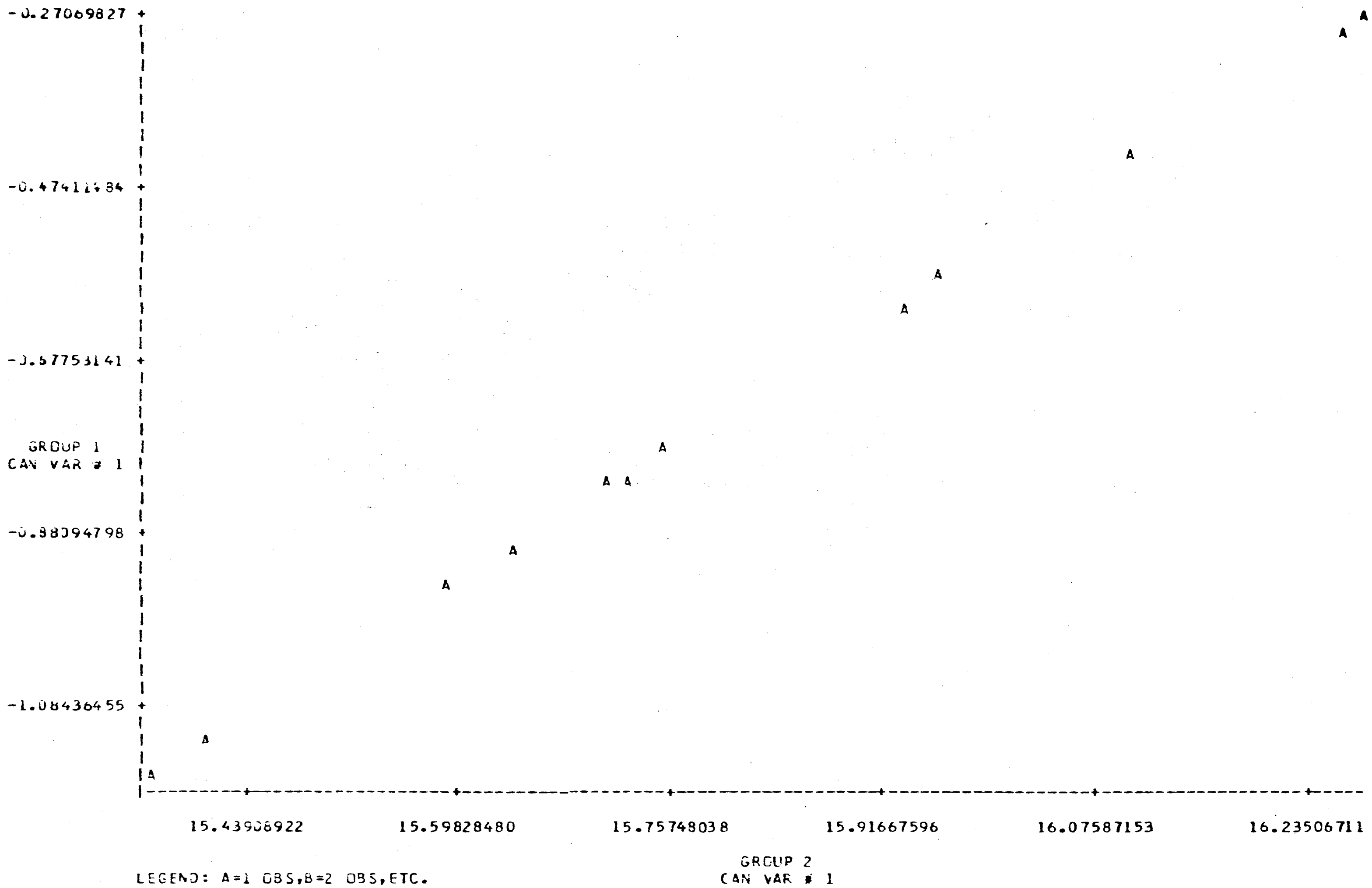


Figure 3.62. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Temperature at 50 cm Depth with the First Set of Variables.

TABLE 3.64

CANONICAL CORRELATION ANALYSIS FOR TEMPERATURE AT 50 CM DEPTH WITH THE SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.16862503	-7.19344868	1.00000000	204.79898	35	0.0001
2	-0.74633173	14.14986428	0.99530771	45.96086	24	0.0045
3	0.65943002	-15.04857005	0.97451068	20.27015	15	0.1613
4	0.66343951	-3.25800540	0.67511900	3.82970	8	0.8728
5	-0.86510486	34.16119728	0.29007745	0.48343	3	0.9196

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	ETR	PSI	PAR	OTHER	FORBS
VAR # 1	-0.444954	-0.352186	0.969398	-0.155654	0.061406
VAR # 2	0.531010	-0.614581	0.169518	-0.502282	-0.608065
VAR # 3	0.382115	0.181252	0.163999	0.125455	-0.278049
VAR # 4	0.560945	0.493085	0.059921	-0.727539	-0.258605
VAR # 5	-0.243566	0.471455	0.032338	-0.422413	-0.694477

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	MAY50	JUNE50	JULY50	AUG50	SEPT50	OCT50	NOV50
VAR # 1	0.008521	-0.221941	-0.122276	-0.853325	-0.072734	-0.095508	0.585204
VAR # 2	-0.073270	-0.093807	-0.445394	0.027450	-0.238853	-0.326564	0.208833
VAR # 3	0.126608	0.419117	0.200698	-0.143840	0.136540	-0.127963	-0.634569
VAR # 4	-0.003554	0.043698	0.126388	-0.115207	0.197631	-0.282739	-0.335861
VAR # 5	0.382363	0.464250	0.492820	0.052380	0.553814	0.496117	-0.181900

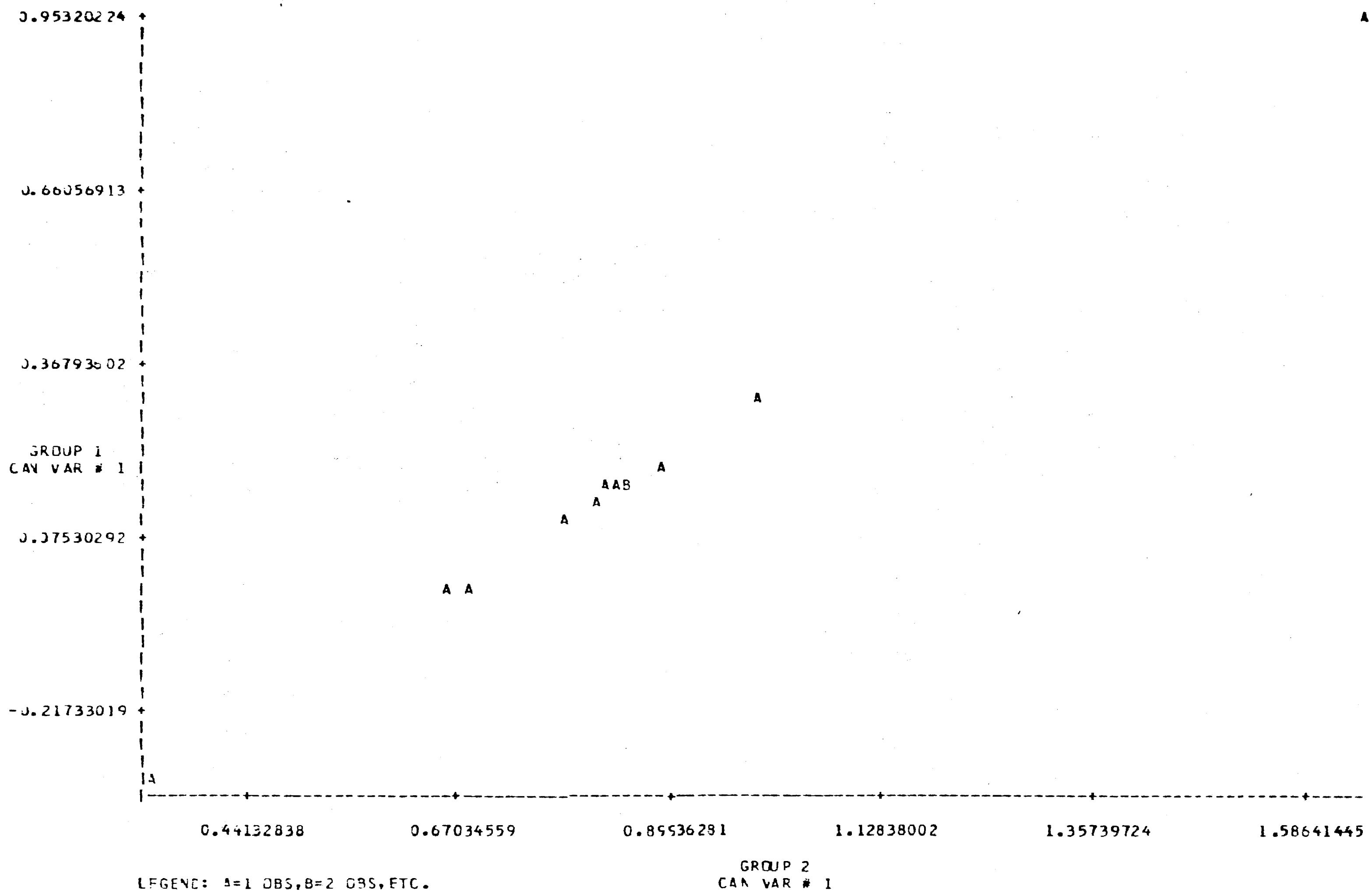


Figure 3.63. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Temperature at 50 cm Depth with the Second Set of Variables.

total moisture content of May, June, July, August, September, October, and November. The canonical correlation of the first variates was 1.0 (Table 3.65) (Prob>Chi-SQ = .0001). This can be interpreted as low Scr values (-.61), high Asc values (.64), and high Aha values (.81) are highly associated with moderately high May values (.48), high June values (.51), high July values (.55), high August values (.52), high September values (.45), high October values (.43), and high November values (.48) (Figure 3.64). High counts of Asc and Aha are associated with relatively high total moisture content in May through November in terms of the original data.

The other group of vegetation variables are Etr, Bst, Par, other grasses, and forbs with the total moisture content of May through November. The canonical correlation of the first variates was 1.0 (Table 3.66) (Prob>Chi-SQ = .0001). This can be explained as moderately high Etr values (.36), low Pst values (-.61), and high Par values (.53) are highly associated with moderately high July values (.53), moderately high August values (.50), moderately high September values (.52), moderately high October values (.52), and moderately high November values (.52) (Figure 3.65). High counts of Etr and Par are highly associated with relatively high total moisture content in terms of the original data.

Summary and Conclusions

Relationships between eleven dominant plant species and fourteen different soil chemical properties using the canonical correlation technique were studied in different combinations. Soil-moisture, as well as soil-temperature data were introduced to the study as a different group

TABLE 3.65

CANONICAL CORRELATION ANALYSIS FOR TOTAL MOISTURE CONTENT WITH THE FIRST SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.37283900	-0.51189887	1.00000000	184.46172	35	0.0001
2	0.06288369	-1.51128479	0.95546097	22.35956	24	0.5581
3	-0.33767193	3.38277691	0.80001427	8.93536	15	0.8812
4	0.36455886	-0.49010066	0.64020932	3.31593	8	0.9130
5	1.17361359	-2.07228653	0.26964444	0.41518	3	0.9334

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	SCR	BGR	ASC	AHA	PVI
VAR # 1	-0.612264	-0.245751	0.644993	0.813349	0.439021
VAR # 2	-0.094116	0.747971	0.424289	0.195307	0.159059
VAR # 3	0.072164	-0.181502	-0.511876	0.424217	-0.857081
VAR # 4	-0.067904	0.585477	-0.371278	0.326423	-0.073714
VAR # 5	0.778753	-0.066486	-0.064026	-0.117497	-0.204789

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV
VAR # 1	0.477133	0.512508	0.554596	0.517762	0.448637	0.428279	0.475150
VAR # 2	0.318307	0.427080	0.337905	0.318072	0.318637	0.278297	0.215312
VAR # 3	0.351351	0.410746	0.238247	0.262599	0.256476	0.249539	0.244322
VAR # 4	0.570441	0.326944	0.325549	0.422625	0.489543	0.462447	0.475443
VAR # 5	-0.335466	-0.420949	-0.421069	-0.364296	-0.320729	-0.376173	-0.334483

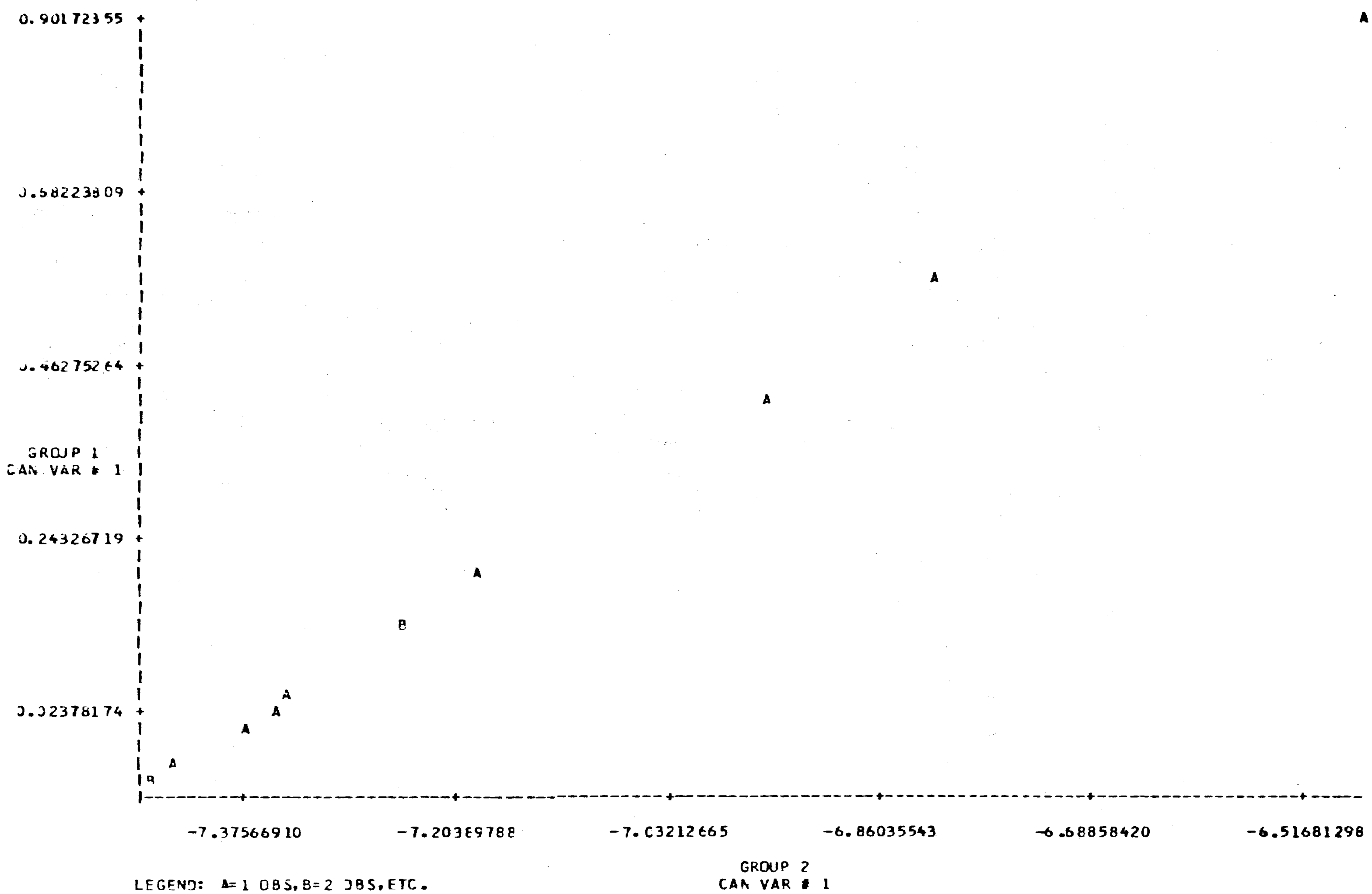


Figure 3.64. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Total Moisture Content with the First Set of Variables.

TABLE 3.66

CANONICAL CORRELATION ANALYSIS FOR TOTAL MOISTURE CONTENT WITH THE SECOND SET OF VARIABLES

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.72992023	-1.21332746	1.00000000	204.35066	35	0.0001
2	-0.28665554	0.39853242	0.99514171	33.60915	24	0.0916
3	-0.25032588	-2.16334925	0.76154495	8.10921	15	0.9194
4	0.33897773	-1.76974741	0.56604488	3.33860	8	0.9114
5	1.19315249	0.15364093	0.44507111	1.21415	3	0.7531

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	ETP	PST	PAR	OTHER	FORBS
VAR # 1	0.359433	-0.612759	0.532938	0.061093	0.169944
VAR # 2	0.792413	0.209671	-0.094238	-0.738328	-0.887167
VAR # 3	-0.107716	-0.166061	0.436551	-0.651009	-0.079393
VAR # 4	-0.338774	0.364926	0.655210	-0.158903	-0.255896
VAR # 5	0.341350	0.647928	-0.295330	-0.045573	0.335064

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV
VAR # 1	0.338722	0.324814	0.527450	0.501170	0.516467	0.520881	0.524861
VAR # 2	-0.135895	-0.301712	-0.231513	-0.279160	-0.256679	-0.294093	-0.201486
VAR # 3	0.309816	0.097079	0.086219	0.192245	0.244034	0.191580	0.222617
VAR # 4	-0.660651	-0.699183	-0.661976	-0.636884	-0.565643	-0.580404	-0.595921
VAR # 5	-0.412003	-0.398245	-0.242053	-0.174734	-0.196576	-0.111737	-0.101545

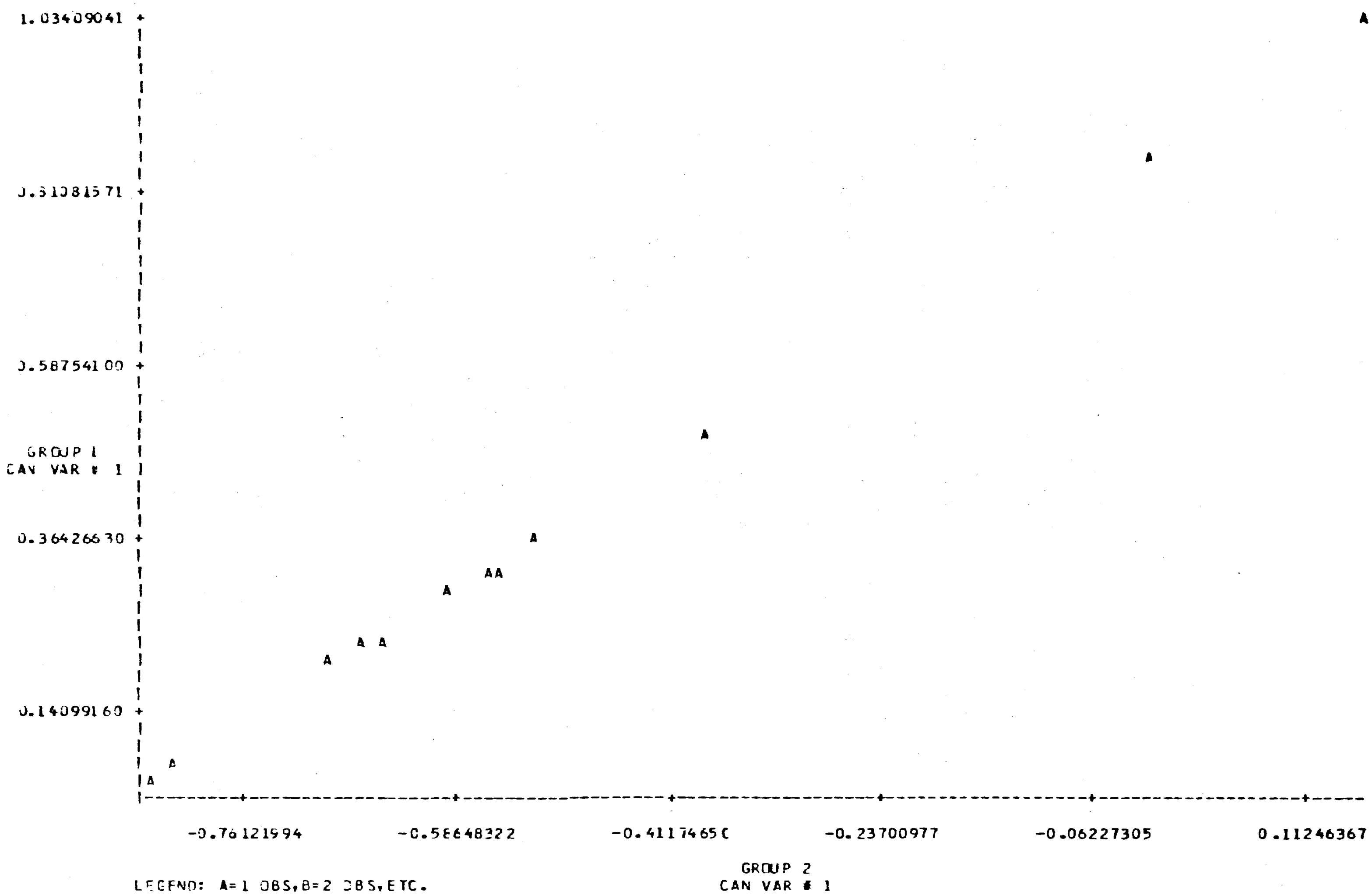


Figure 3.65. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for Total Moisture Content with the Second Set of Variables.

of variables with that of vegetation counts. A significant correlation was found between different plant species and many of the chemical properties and soil-moisture data. It would be more helpful if these results were accompanied by an intensive physiological plant study to correlate the different physiological and morphological plant properties, such as root systems, under these conditions. Such a study would provide more information about the native grasses and their habitat, especially those of soils.

As shown by the results of the canonical correlation, some species are highly correlated with CEC, organic matter, thickness of A and B horizons and Clay content. Other species are highly correlated with fine sand and very fine sand fractions. This can be explained by the diversity of the plant species in terms of their physiological and genetic make up.

Moisture results showed that many plant species were highly correlated with relatively high total moisture content. Temperature results showed that most plant species correlated with high temperatures from May through October and with low temperatures in November, which is the same pattern of the original data.

Some of the results of this chapter will be discussed in detail in some other chapters.

CHAPTER IV

SOIL-PLANT RELATIONSHIPS IN THE STABILIZED SAND DUNES OF NORTHWESTERN OKLAHOMA

Abstract

Ten dominant plant species on the stabilized sand dunes of Northwestern Oklahoma were noticed to vary sharply along a transect on an east-west facing slope. The frequencies covered by these species were used in the canonical correlation technique as the first group of variables with those of measurable soil properties as the second group of variables. Soil-moisture and soil-temperature data also were introduced to the study.

Soil-moisture was found to have a detrimental effect on the distribution of plant communities on the soil surface. Cation exchange capacity, clay content, organic matter, and the thickness of A and B horizons also made a significant contribution in controlling the type and the frequency of the plant species. Presence or absence of the argillic horizon in a certain position controls the availability of soil-moisture and the latter has a direct influence on the plant species distribution.

Introduction

In recent years great emphasis has been directed towards soil-plant relationships. This relationship is an important part of the concept of soil productivity (Bartili, 1978). Soil-plant relationships are greatly influenced by any soil property that controls nutrient or moisture supply to the plants. Understanding such a relationship and the environmental factors surrounding both soil and plants will help soil scientists, range management people, soil conservation workers, and many others to overcome the difficulties that are associated with productivity and management of our soils. The first prerequisite to any successful range improvement practice and associated grazing program is an understanding of the soil types and plant species present and the soil-plant relationships. Soils and vegetation are the basis for determining range sites and range sites are the fundamental units for range management (Powell and Baker, 1974).

The measurable soil properties that influence soil-plant relationships, such as effective depth of roots, organic matter content, particle size distribution, cation exchange capacity, kind and amount of clay minerals present, permeability, available water-holding capacity, shape and degree of soil slope, and many others, are included in any soil survey to be used as an important tool in soil production and management indices. Most of these soil properties are included in this study to help explain variations in plant communities and soils within the sandy ecotones of Northwestern Oklahoma and to obtain insight into soil genesis and soil-plant relationships in the stabilized sand dunes of the same area.

Results and Discussion

Soils of the Area

The two sites of this study are located on rolling, stabilized sand dunes, which consist of mainly Pratt-Tivoli soil associations. It is a group of sandy soils occurring on the sandy mantle strips north of the Canadian, Cimmarron, and Salt Fork Rivers. Sands have been reworked by wind action to form a duney strip. Sand dunes in Harper County are believed to have been deposited during the Pleistocene Age (Soil Survey, Harper County, 1951). As shown in the Block diagrams of both sites, these soils are either very deep with undeveloped soil profiles occupying the summit and the shoulder positions of the slopes or soil with a well-developed soil profile having a thick argillic horizon in the lower positions of the slope. Some of the deep sandy soils have a buried argillic horizon at various depths. Profile descriptions as well as other soil features of these two sites are discussed elsewhere in this study.

Vegetation Study

As shown in Tables 4.1 and 4.2, plant species vary sharply from one slope position to another in both sites. On the west-facing summit of the first site, the dominant plant species are sand dropseed, forbs, and other different species of grasses with low percentages of cover as individual species, but they have up to 23.6%, collectively. On the shoulder of the west-facing slope, the same plant species appears to be dominant, except that switchgrass appeared with a 3.3% cover on this position. On the west-facing toe slope, bluegrama, Texas bluegrass, sand dropseed, and forbs makes the major plant species. The one difference between the east and the west-facing summits is the dominance of sand paspalum with 27.9% cover on the east-facing summit, while the cover is only 6.0% on the west-facing summit. The east and the west-

TABLE 4.1

RANGE PLANT SPECIES AND PERCENTAGES OF COMPOSITION ON THE FIRST SITE OF SAND DUNES

SPECIES	PERCENTAGES OF COMPOSITION					
	EAST SUMMIT	EAST SHOULDER	EAST TOE SLOPE	WEST TOE SLOPE	WEST SHOULDER	WEST SUMMIT
SAND DROPSEED	16.3 *	14.2 *	16.1	4.8	14.0 *	30.9 *
BLUE GRAMA	5.1	1.8	23.4 *	4.6	5.2	0.2
LITTLE BLUESTEM	4.1	1.6	1.1	3.9	0.0	0.0
SAND BLUESTEM	2.1	0.9	2.2	29.3 *	0.0	0.0
SWITCHGRASS	0.6	3.3	3.2	0.4	0.0	0.0
SAND LOVEGRASS	0.0	3.7	0.0	6.1	0.5	0.0
SAND PASPALM	6.0	8.7	0.4	0.7	5.2	27.9 *
TEXAS BLUEGRASS	0.1	4.7	26.1 *	0.0	0.0	0.0
FORBS	37.9 *	35.8 *	24.8 *	38.4 *	39.1 *	37.6 *
OTHER GRASSES	23.6 *	20.2 *	2.8	11.9 *	35.1 *	3.2
SHRUBS	4.1	4.3	0.0	0.0	0.7	0.2

*THE COMMON SPECIES IN THAT PARTICULAR POSITION.

TABLE 4.2

RANGE PLANT SPECIES AND PERCENTAGES OF COMPOSITION ON THE SECOND SITE OF SAND DUNES

SPECIES	PERCENTAGES OF COMPOSITION					
	EAST SUMMIT	EAST SHOULDER	EAST TOE SLOPE	WEST TOE SLOPE	WEST SHOULDER	WEST SUMMIT
SAND DROPSEED	41.0 *	28.7 *	31.8 *	4.6	15.4 *	22.6 *
BLUE GRAMA	0.0	0.0	0.0	3.1	0.0	0.0
LITTLE BLUESTEM	0.0	0.2	1.0	11.1 *	2.8	3.7
SAND BLUESTEM	0.0	0.0	0.2	4.8	0.0	5.6
SWITCHGRASS	0.0	0.0	0.7	13.4 *	4.9	3.9
SAND LOVEGRASS	11.0 *	14.0 *	10.1 *	7.0	5.9	14.5 *
SAND PASPALM	25.7 *	15.6 *	11.9 *	7.9	10.4 *	6.1
TEXAS BLUEGRASS	0.0	0.0	0.0	17.4 *	29.4 *	0.0
FORBS	12.9 *	24.7 *	35.2 *	24.5 *	21.6 *	31.7 *
OTHER GRASSES	8.0	4.8	7.7	6.1	7.6	5.6
SHRUBS	0.3	11.3	0.0	0.0	1.3	5.9

*THE COMMON SPECIES IN THAT PARTICULAR POSITION.

facing shoulders showed no significant differences in the plant communities' composition. On the east-facing border of the toe slope, sand bluestem covers 29.5% compared to 2.2% cover on the west facing border of the same position. Sand lovegrass is more abundant on the east-facing toe slope and is absent on the west-facing slope.

On the second site, the west-facing summit is dominated by sand dropseed, sand paspalum, sand lovegrass, forbs, and other grasses of different species. It differs from that of the east-facing summit by the absence of little bluestem, sand bluestem, and switchgrass. The differences between the east and the west-facing shoulders is the presence of Texas bluegrass with 29.4% cover on the east-facing slope and its absence on the west-facing slope. Sand dropseed is present with a maximum percent cover (30.9%) on the east-facing summit of the first site and it is present in a maximum percent cover on the west-facing summit (41.0%) of the second site. Both summits have a buried argillic horizon, while it is absent in the other two summits. The same pattern can be noticed for sand paspalum.

In most of the studies done on this subject, soil-moisture is considered as the number one factor that controls the type and the frequency of plant species. In general, plant ecologists agreed that within climatic regions, quantity and availability of soil-moisture are major determinants of geographic distribution of plant species. Equally important in explaining plant distribution within a climatic zone is variation in the force that can be exerted by different species to remove water from soil (Farrel et al., 1975). As can be seen from the results of the canonical correlation, a high correlation was found between high percentages of Sporoblus cryptandrus (sand dropseed), Andropogon hallii (sand bluestem), Panicum virgatum (switchgrass), Eragrostis trichodes (sand lovegrass), Poa archnifera (Texas bluegrass), Paspalum stramineum (sand paspalum), and forbs and high total moisture content. Certain types of plant species are dominant on positions of high moisture content. The rest of the plant species, which did not correlate with high total moisture content, seem to prefer a drier habitat or can grow well in less moisture content than others. As an example, Bouteloua gracilis (bluegrama) is usually the dominant species on low moisture sites, while Andropogon scoparius (little bluestem) appears to thrive on damp sites (Majures, 1975). Also Andropogon hallii (sand bluestem) was found to have a higher emergence in soils with higher moisture availability after treatment with pathogenicide (Stubbendieck and Wayne, 1975).

In another study, Briske and Wilson (1977) found that Bouteloua gracilis (bluegrama) seedlings can initiate adventitious roots during severe droughty conditions in the surface soil. In general, the yield of shortgrass plains was found to be a function of current season precipitation, while plant composition and ground cover were more closely related to previous season precipitation (Harold et al., 1975). Andropogon hallii (sand bluestem) and Paspalum stramineum (sand paspalum) production increased as a result of an increase in the available soil-water content (Briton et al., 1978).

As shown in Tables 4.1 and 4.2, some plant species have a higher percentage of cover on positions that have an argillic horizon, which simply means that higher soil moisture is available to the plant roots of such species. A very high correlation was also found between high counts of most of the plant species and high clay content and cation exchange capacity. Ca, Mg, and K have different correlations with different plant species. Generally, Mg and K have a high correlation with the same plant species. This could be due to the homogeneity of the positions in terms of the amounts of these cations. A very high correlation was found between high organic matter content and the thickness of A and B horizons and high frequencies cover of most of the plant species.

pH values seem to have a different effect on plant species. Some species, such as Bouteloua gracilis (bluegrama), Andropogon hallii (sand bluestem), Eragrostis trichodes (sand lovegrass), Panicum virgatum (switchgrass), Sporoblus cryptandrus (sand dropseed), Poa arachnifera (Texas bluegrass), and other grasses, were highly correlated with high values of pH. The rest of the species have nonsignificant correlations. Species, such as Bouteloua gracilis (bluegrama), Poa arachnifera (Texas bluegrass), Panicum virgatum (switchgrass), Eragrostis trichodes (sand lovegrass), and forbs, were found to have a very high correlation with fine and very fine sand fractions. The rest of the species did not show any significant pattern.

Summary and Conclusion

Ten dominant plant species were used in the canonical correlation as the first set of variables with weighted measurable chemical and physical soil properties. Soil-moisture and temperature also were introduced to the system to find out what the most important soil properties are that control the type and frequency of different plant species. Soil-moisture seems to have a great influence on the distribution of the plant communities. Presence of the argillic horizon, which has a higher

CEC and percent clay content, has a direct effect on soil-moisture availability and the latter has a great influence on the plant distributions. Some plant species prefer drier habitats than others which did not highly correlate with high total moisture content. Organic matter, pH, and thickness of A and B horizons are very important soil properties in the existence and distribution of most of the plant species studied. A physiological plant study on each species is required to provide more information about plant individuals and their physiological behavior under such conditions.

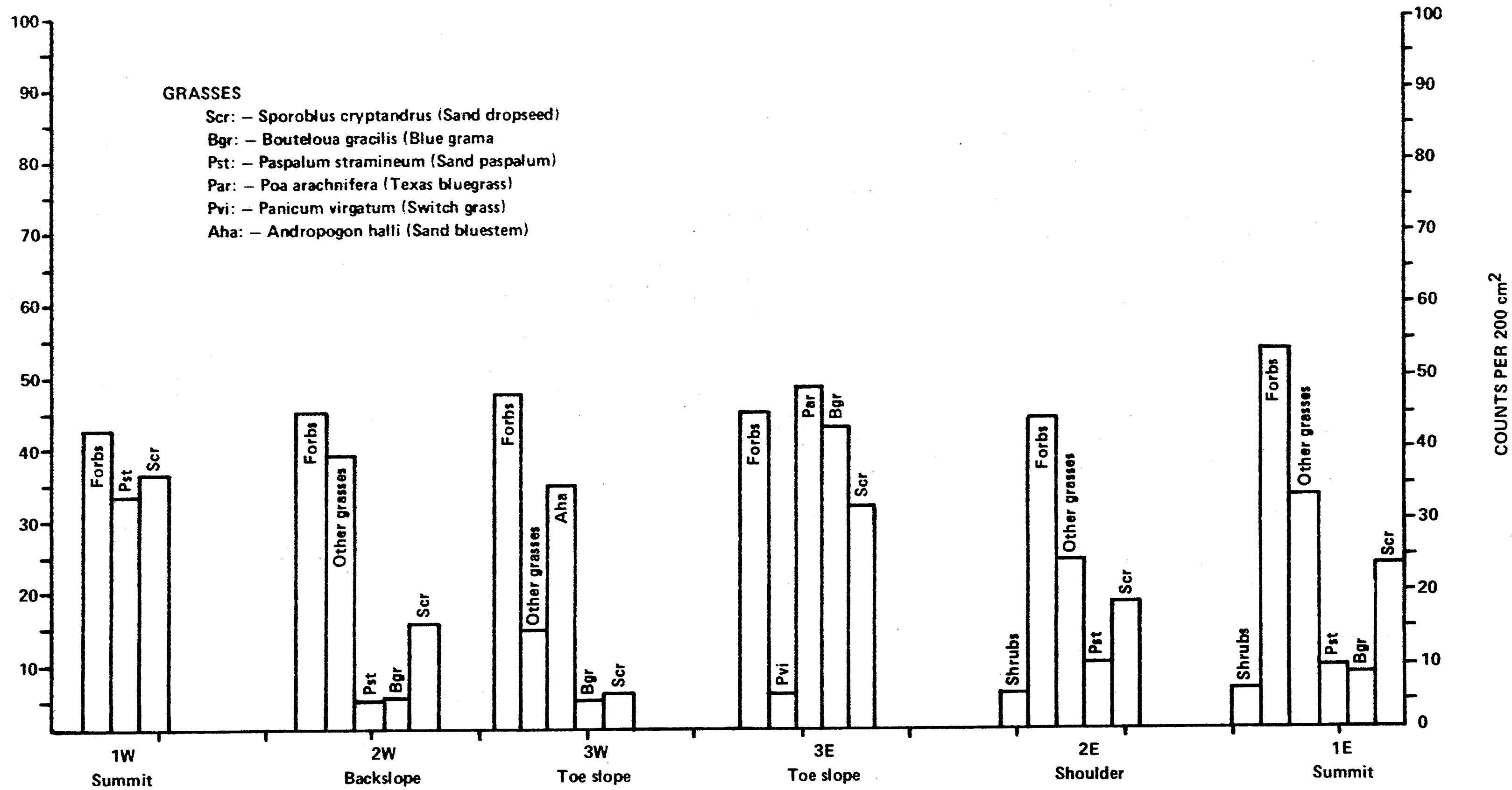


Figure 4.1. Ecotone 1 East and West Showing Vegetation Pattern.

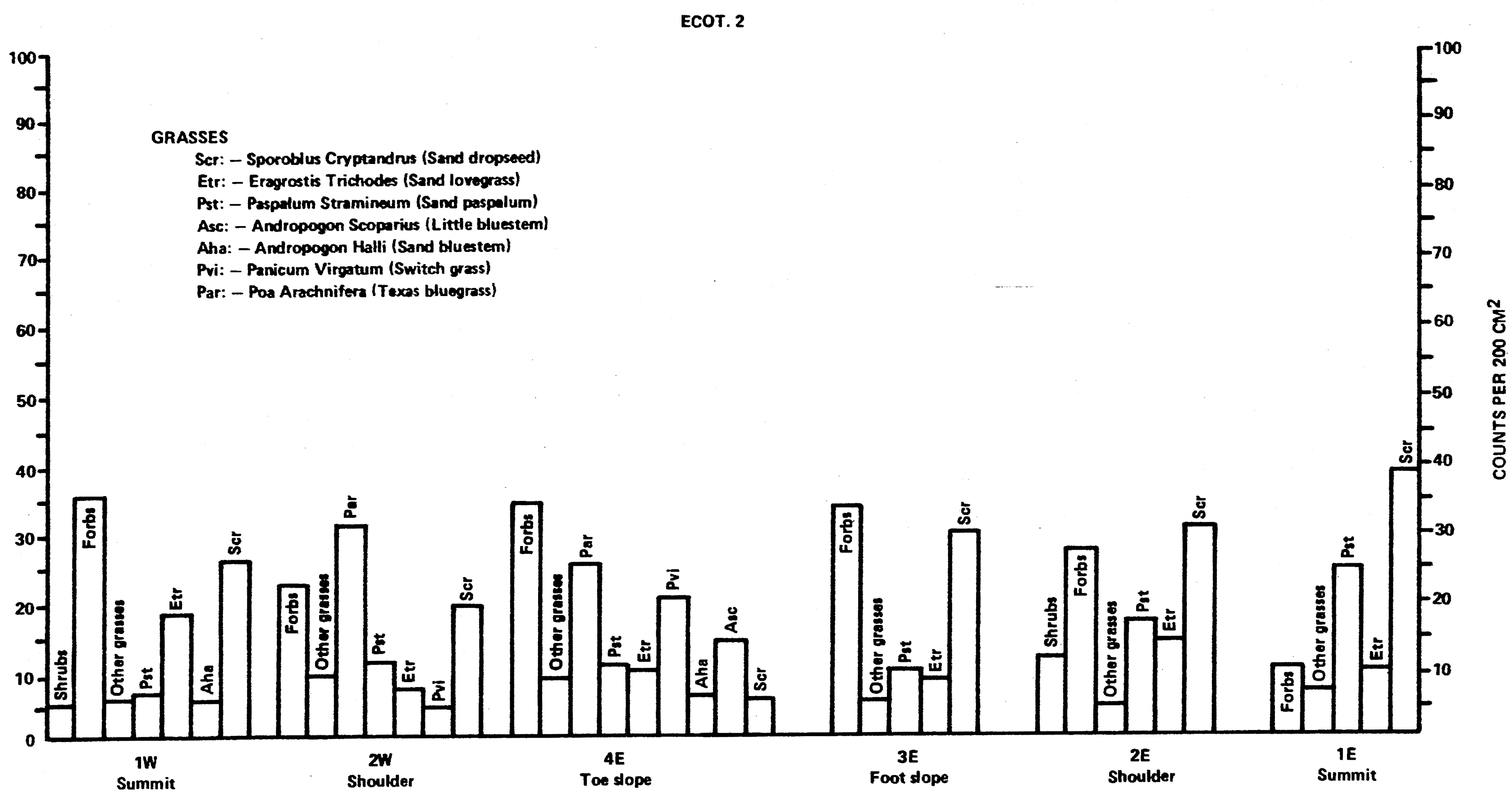


Figure 4.2. Ecotone 2 East and West Showing Vegetation Pattern.

CHAPTER V

SOIL GENESIS, MORPHOLOGY, AND THE MAPPING UNITS OF STABILIZED SAND DUNES

Abstract

In one of the two sites selected for this study, a trench was opened from summit-to-summit in order to sample and describe the soil pedons. Figures 5.1 and 5.2 are Block diagrams sketched in the field sharing an accurate representation of the sequence of the genetic horizons and the different stratas to a depth of about five meters. A total of six pedons were sampled and described from each site. Most of the soils on the summit and shoulder positions are weakly-developed soils and the soils on the toe and back slopes are deep, well-developed soils. A buried argillic horizon, present in the west-facing summit of the first site at a depth of 260 cm, extends to the back slope position of the east-facing slope. In the second site, a buried argillic horizon, present in the east-facing summit at a depth of about 300 cm, extends to the back slope of the west-facing slope.

These soils were classified as one association, namely the Pratt-Tivoli soil association. A more practical and precise definition of the mapping unit is required for better soil management. A new name on the level of sub-group should be added to these sandy soils with a buried argillic horizon. Such a change will provide more information to the

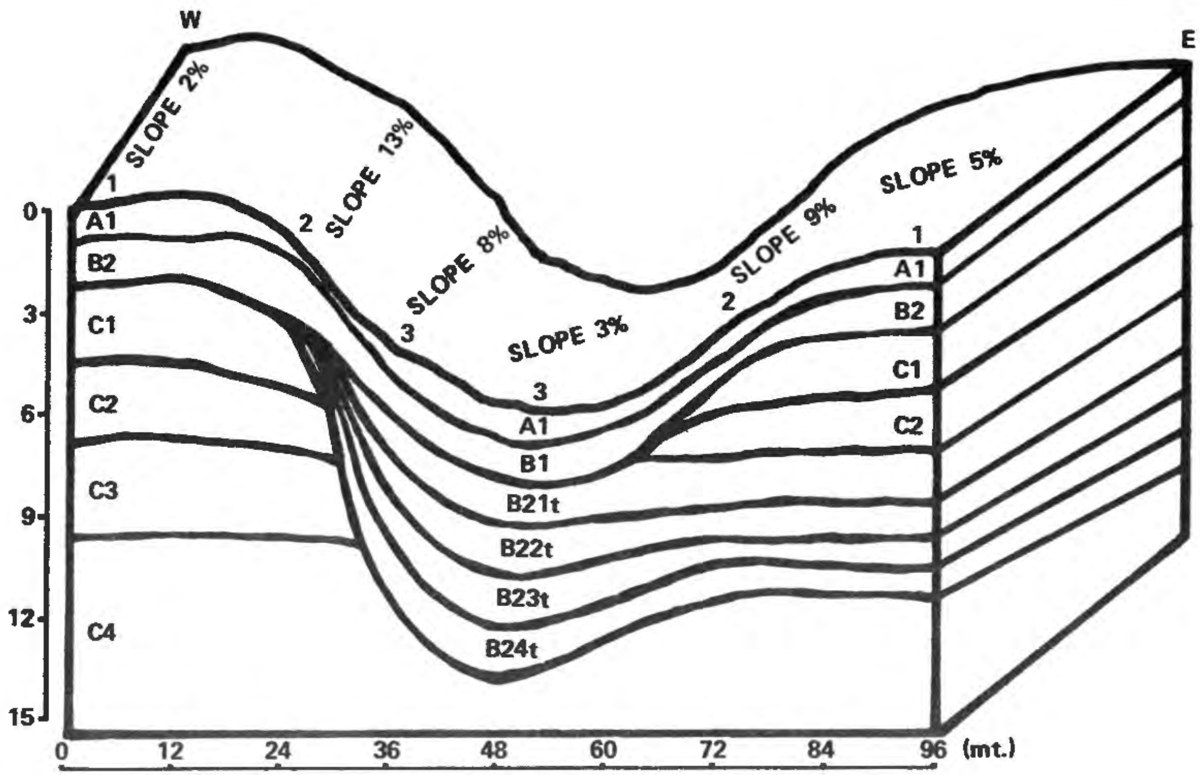


Figure 5.1. Block Diagram of Ecotone 1 East and West Showing the Positions of the Selected Pedons and Their Horizons.

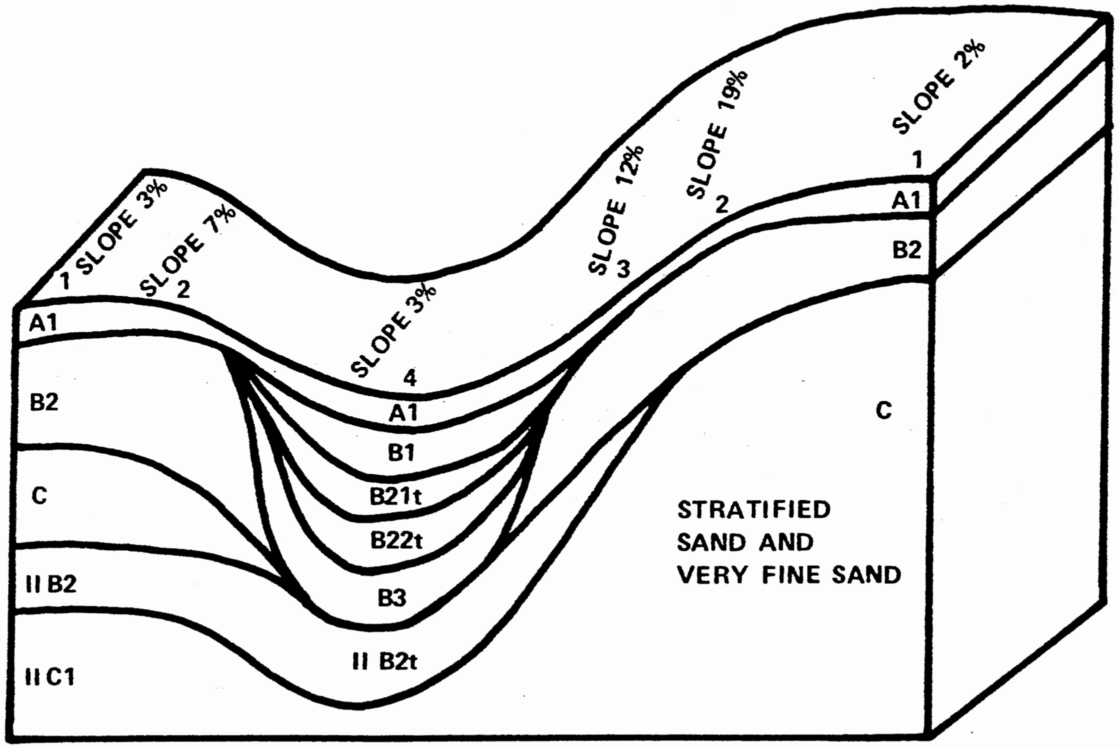


Figure 5.2. Block Diagram of Ecotone 2 East and West Showing Positions of the Selected Pedons with the Slope Percentages.

reader, especially for the range management workers. A cluster analysis technique was used using measurable soil properties to show the grouping trends of the genetic horizons of the two areas. Four groups of the genetic horizons were recognized based on chemical properties. Grouping of some B1, B2, B2t, and C horizons with A horizons in one group indicates the difficulty in separating the lower boundary between the solum and the parent material of a weakly-developed soil. Cluster analysis, based on percentage cover of vegetation, shows that summits, shoulders, and toe slopes support different plant communities as they differ in the number and sequence of the genetic horizons.

Introduction

The objective of this chapter is to help define the mapping units in sandy areas as well as to obtain insight on soil genesis of the stabilized sand dunes of Northwestern Oklahoma. Pratt-Tivoli is the main soil association in that area, which consists of deep sandy soils that have been formed on a steep sand dune under a cover of tall native grasses. These soils were formed as a result of reworked sand by wind action from adjacent rivers. Slope changes in these sandy areas resulted in changes in the number and the sequence of the genetic horizons present. Due to the importance of the sandy area in Harper County in the field of range management, more precise information about the soil of different range sites is required. This study will provide valuable information about the soil and its relationships with the native vegetation. The increasing number of objectives which soil surveys now serve in both agricultural and non-agricultural areas, requires that greater emphasis be placed on more accurate and precise definitions of the basic interpretive elements of surveys, namely the mapping unit. In many cases, only a small portion of the landscape is investigated by soil scientists in delineating a mapping unit and very often these observations do not reflect the magnitude of the inclusions present, which might be quite important to describe them separately.

Results and Discussion

Soil Morphology and the Mapping Units

As can be seen from the Block diagrams of the two areas (Figures 5.1 and 5.2) and the morphological description of the pedons, two major soils can be recognized in the stabilized sand dunes of Northwestern Oklahoma. Very deep, weakly-developed, sandy in texture, somewhat excessively drained soils occupy the summit and back slope positions of the sand dunes. Stratified sand and very fine sand are the main characteristics of the parent material. The surface A horizon is loamy sand with medium weak granular structure. The thickness of this horizon varies according to the slope position. The B (cambic) horizon of these soils is loamy sand to sandy loam in texture, with a weak subangular to prismatic breaking to subangular and angular blocky structure. The most important feature of these sandy soils is the presence of buried argillic horizons at various depths. In the first site of the sandy area, this horizon, present at a depth of 260 cm in the west-facing summit, extends to the back slope of the east-facing slope. In the second site, the buried argillic horizon, present in the east-facing summit at a depth of about 300 cm, extends to the back slope of the west-facing summit. The presence of such a horizon in these sandy soils is very significant. Most of the grass roots extend down to reach the argillic horizon to obtain its requirement of available moisture. Although this horizon is beyond the defined limits of the solum, it represents the main source of moisture for the native grasses in the area. In classifying sandy soils according to the seventh approximation (1975), the importance of this buried horizon was not recognized, which influences their interpretations very greatly in terms of soil productivity and management. The other type of soil occupies the foot slope and toe slope positions of the two areas, which consists of deep, well-developed soil profiles. Clay content, cation exchange capacity, and available moisture in these soils are very high compared to those sandy soils in the summits.

A typical soil body, depicted as a mapping unit on a detailed soil map, may include other soils to the extent of about 15% as defined by the soil survey manual (1951). In the stabilized sand dunes of Northwestern Oklahoma, the inclusions are more than this defined percentage and require more precise definitions of the mapping unit. Fridland, quoted by Boul et al. (1973), stated that a mapping unit on a detailed soil map may actually include other soils to the extent of about 35% by area rather than the prescribed 5 to 15% of accepted definitions. Classifying these soils as Pratt-Tivoli soil association does not provide enough information about the soil, especially for the range management people and many others (Pendleton, 1915). Harradine (1949), who was primarily interested in whether or not soil types were being mapped accurately in the field and whether the properties that defined such classification units were significant or useful to other research workers, found that soil maps were of limited use, mainly because the classification units are too loosely defined and too often inaccurately mapped. Choosing the suitable mapping unit is important and required for land improvement, which is the key factor in increasing the output of these soils. Properties in the selection of land units for improvement should be based on existing limitations and assessed potential of particular soil type (Floate, 1977).

In many cases, it is quite difficult to separate small soil inclusions from the dominant soil in the area for many reasons. Among them are difficulties which arise in defining criteria used to determine boundaries between mapping units (Ivara, 1979). Also practical cartography limits the separation procedure due to scale of the maps being used. James and Springer (1965) pointed out that small acres, less than one acre in size, of different soils are included in many delineations. It is not feasible to separate areas of this size on a map at the scale of four inches to the mile. In fact, many efforts are made to separate soils that respond differently to management, based on some suite of soil properties. The decision as to which properties to use is usually within the domain of the soil survey party. Degree of slope, soil moisture regime, and surface soil texture were used in many cases to separate the different mapping units (Ivara, 1979).

Cluster Analysis

A total of 61 genetic horizons from two areas were used in this study using 14 measurable chemical and physical soil properties in one step, and 11 dominant plant species in another separate step. Normalization of the data was based on the Talkington (1967) procedure. The similarity matrix was then converted to a dendogram using the unweighted average agglomerative procedure. The genetic horizons were then classified into different groups according to their similarity level. The information theory by Norris (1971) was applied in construction and classification of the transition matrices. Cluster analysis technique was used by many people as a tool in grouping different soils according to its different properties. The earliest numerical approach to classification of the soil was by Hole and Hironaka (1960). Many people argued about the problems in selecting the soil properties that can be used in numerical classification. The chemical data, such as cation exchange capacity, percent clay content, extractable cation, soil pH, etc. are always continuous variables and cause no trouble in the analysis. However, most of the morphological data, such as soil texture, structure, and consistency, are usually discrete or multistate variables and are troublesome in the analysis (Rodney, 1968). The aspects of coding, transformation of quantitative characters, and that of weightage to be given to different characters are needed through examination (Gaikawad et al., 1977). Deletion of some characters probably would be necessary for numerical taxonomy of soils to be effective (Grigal and Arneman, 1969). Sneath and Sokal (1973) suggested deleting any properties that are logical consequences of another and stated that weighting all variables equally, especially where classification is intended to be a natural or basic classification for general use, rather than one for a specific objective. Also Arkely (1976) agreed that in the first stage of analysis, the use of an equal weight to each variable is certainly a sound approach. Sarkar, Bidwell, and Marcus (1966) stated that too closely related characters might exert a double emphasis on a certain property and unduly influence the classification.

The set of data used in this study was based mainly on measurable, continuous chemical and physical soil properties and percentage cover of plant species to avoid complications of the discrete variables of the morphological properties. The groups of the genetic horizons for both sites obtained by the cluster analysis is shown by the dendograms (Figure 5.3).

The groups of the genetic horizons for both sites obtained by the cluster analysis is shown by the dendograms. Mean character difference (MCD) was applied to measure the distance coefficients (Russell, 1967 and Webster, 1972).

With results at the similarity level of D = .70, four groups of genetic horizons can be recognized. All A horizons are clustered in Group 3, which simply means that all A horizons in the different locations have a high similarity index. In the same group there are some wild distributions of some B1, B2, B2t, and C horizons. This could partly be due to the difficulty in recognizing the lower boundary of the solum where the change between the parent material and the solum is very gradual (Dawud, 1979). In another paper, Dawud and Gray (1979) suggested using the bulk density and OM as the main criteria in separating the solum and the parent material. Most of the B2t horizons are grouped in Group 2, although it is interesting to notice that B21t and B22t of 22W, as well as B21t of 24E, are clustered together in Group 4. The only explanation is that these two pedons have maximum illuviation. B21t of 24E has 25% clay with cation exchange capacity of 23 meq/100 gm, while the B21t of 22W has 22.5% clay and 18.6 meq/100 gm CEC. In the B22t of the same location, the percent clay is 31 with a 22.4 meq/100 gm CEC. These values of clay content and CEC are the highest compared with other locations. Since the cluster analysis was based on the

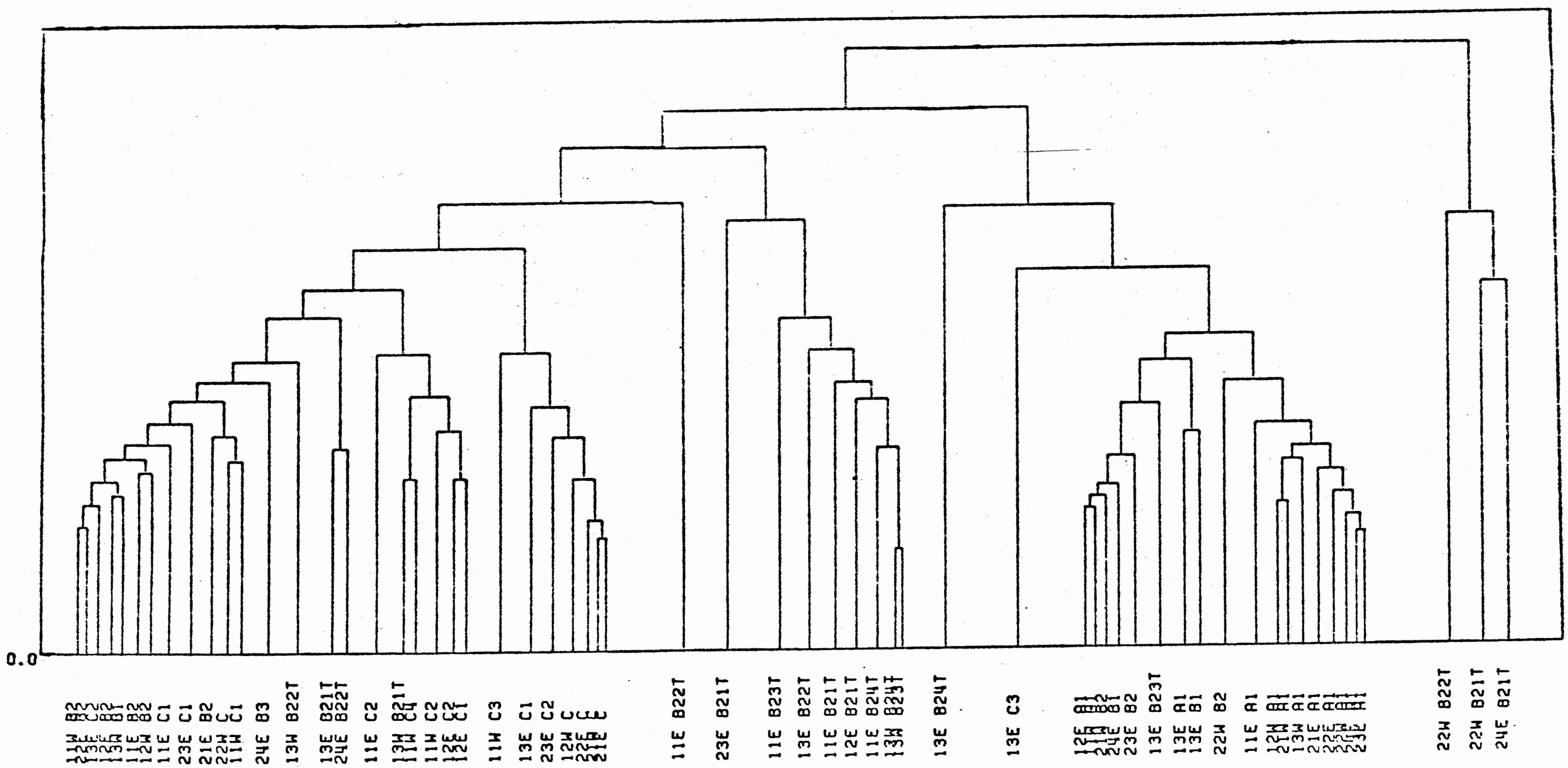


Figure 5.3. Dendogram Cluster of the Pedogenic Horizons of Area One and Area Two.

chemical properties, then this kind of grouping is expected. Most of the B horizons (cambic) and the C horizons (parent material) are grouped in one group (Group 1). For the same reason, it cannot be avoided, especially in the sand dunes area where an alternative layer of fine to very fine sands are present, due to different depositional periods.

In the next stage, three levels of similarity measurements were used to show the different groupings of the pedons according to their genetic horizons. Similarity levels of .70, .65, and .62 were used for all locations (Figures 5.4, 5.5, and 5.6). Locations with a buried argillic horizon, such as 11E, 12E, 13W are clustered in one group. Locations without an argillic horizon, such as 11W, 12W, 21E, 22E, and 21W are clustered in another group, while those locations with a thick argillic horizon, high in clay content, high in cation exchange capacity and higher in soil water-holding capacity are grouped in a different group. In some cases, pedons of different locations, mainly area one and area two, are grouped in one particular group. It was explained that the series, as defined in the context of homogeneity, may not exist at any level in the field even in a small area where the variation of the soil-forming factors are minimal (Dawud, 1979). This leads to a conclusion that the mapping units in these areas should be redefined in a proper way. Dawud (1979) suggested that in similar cases, it is reasonable and safer to call such a unit a soil complex. In the case of the sand dunes of Northwestern Oklahoma where the range management practices are more noticeable, such a general name for the mapping unit may not serve its purpose.

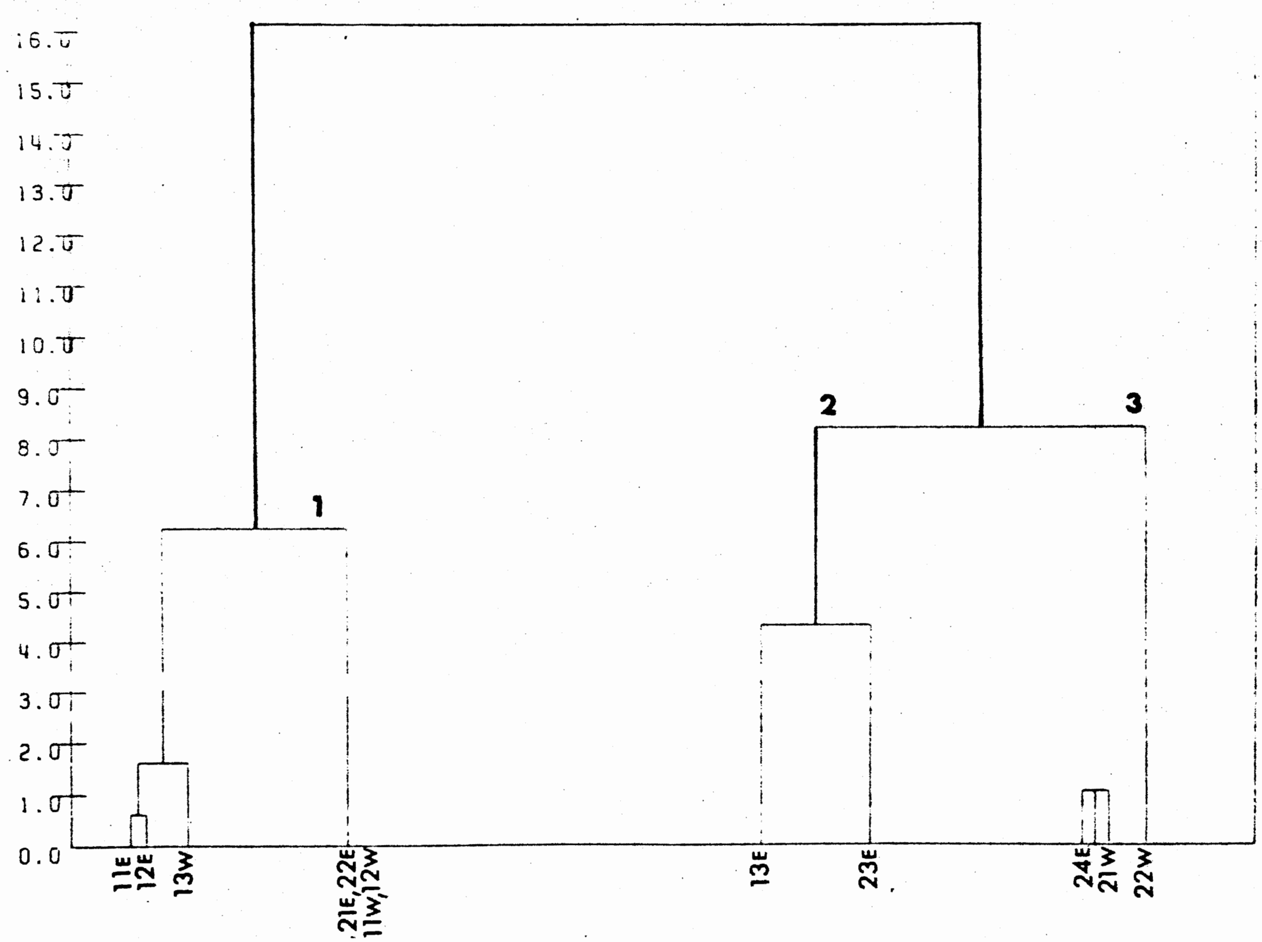


Figure 5.4. Dendogram of the Individual Pedons Obtained from the Primary Dendogram (D = .70).

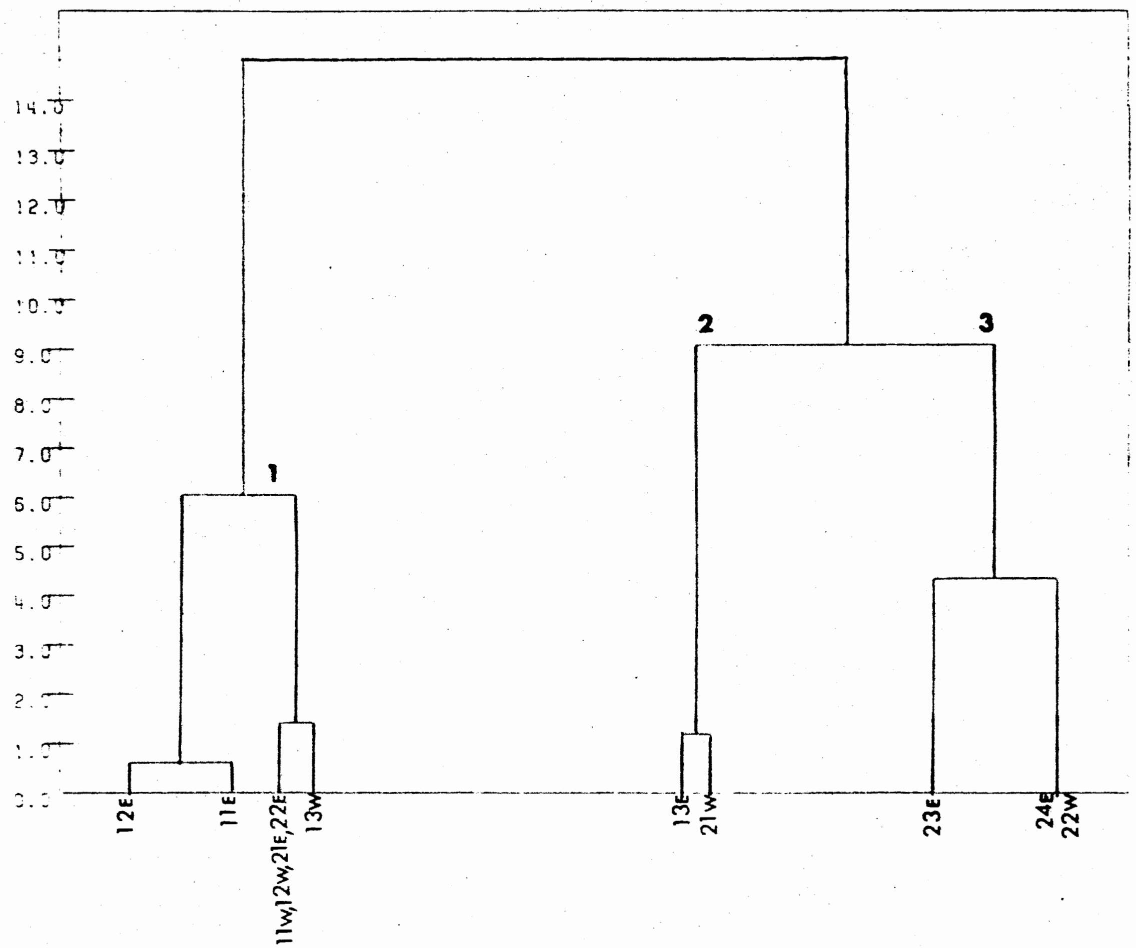


Figure 5.5. Dendogram of the Individual Pedons Obtained from the Primary Dendogram (D = .65).

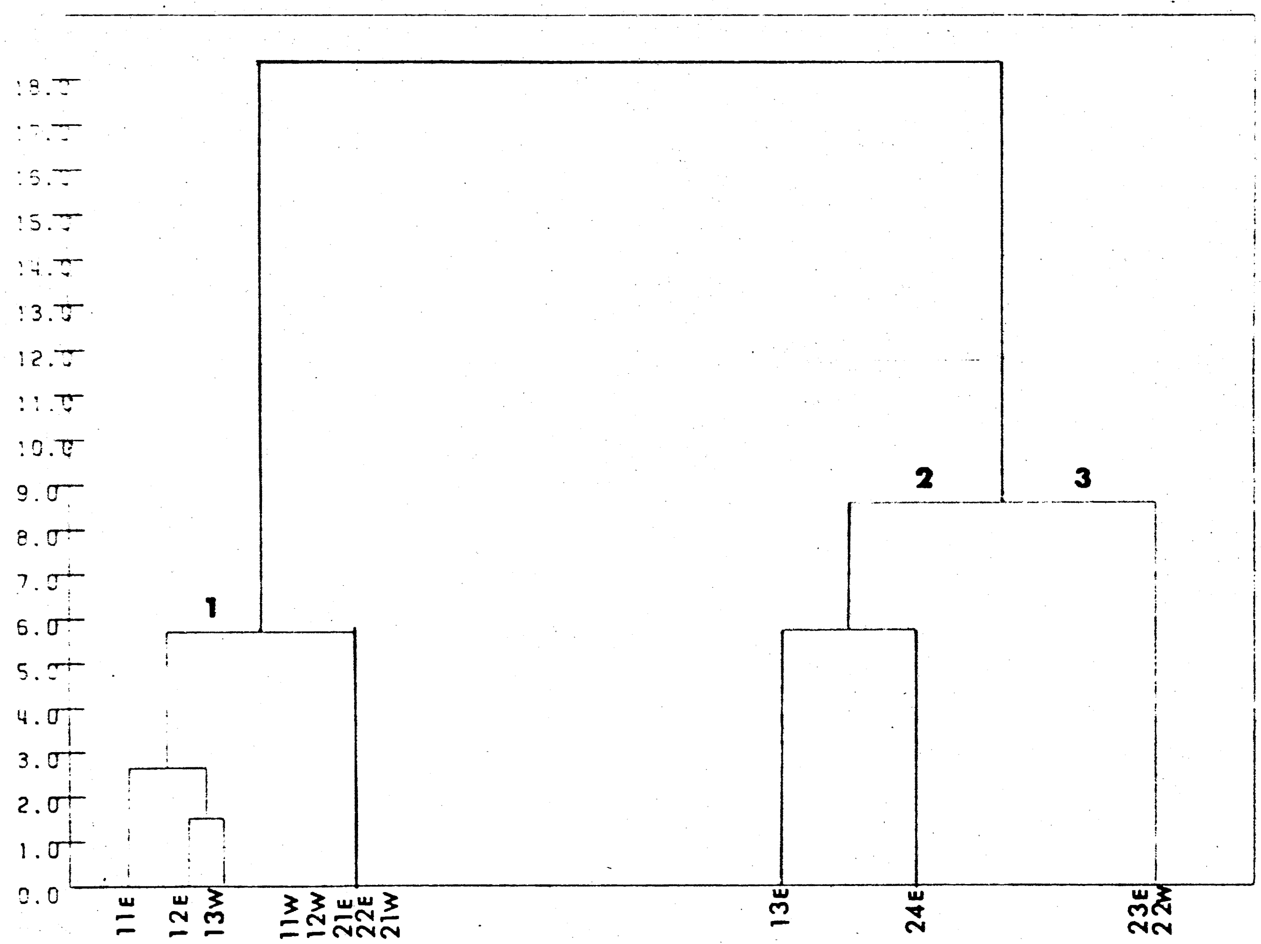


Figure 5.6. Dendogram of the Individual Pedons Obtained from the Primary Dendogram (D = .62).

Cluster Analysis Using Vegetation Counts

At the similarity level of 3.5 the twelve locations were grouped into five major groups. Due to the diversity in the vegetation distributions, the three toe slope positions, namely 13W, 13E, and 24E were represented by a group each of its own (Groups 3, 4, and 5, respectively). Starting by the species of highest percentages, 13W consists mainly of forbs (38.4%), sand bluestem (29.3%), other grasses (11.9%), and sand lovegrass (6.1%). 13E consists of Texas bluegrass (26.1%), forbs (24.8%), blue grama (23.4%), and sand dropseed (16.1%). 24E consists of forbs (24.5%), Texas bluegrass (17.4%), switchgrass (13.4%), and little bluestem (11.1%). The two sites were separated in the groupings as it is shown by the dendogram (Figure 5.7). The summit and the shoulder positions of the first site fall into Group 2, while the summit, shoulder, and backslope positions of the second site are grouped under Group 1, which indicates the differences in the plant communities that dominate both sites.

Summary and Conclusion

In many cases, only a small fraction of the landscape is investigated in delineating a mapping unit and very often these observations do not reflect the magnitude of the inclusions present in the unit, eventhough it is important in the agricultural and non-agricultural areas. The two soils present in the stabilized sand dunes of Northwestern Oklahoma have different soil properties and behave differently in supporting different plant communities. Range management people require more precise definitions of the mapping units of the sandy areas. A significant recognition has to be given to the classification of the

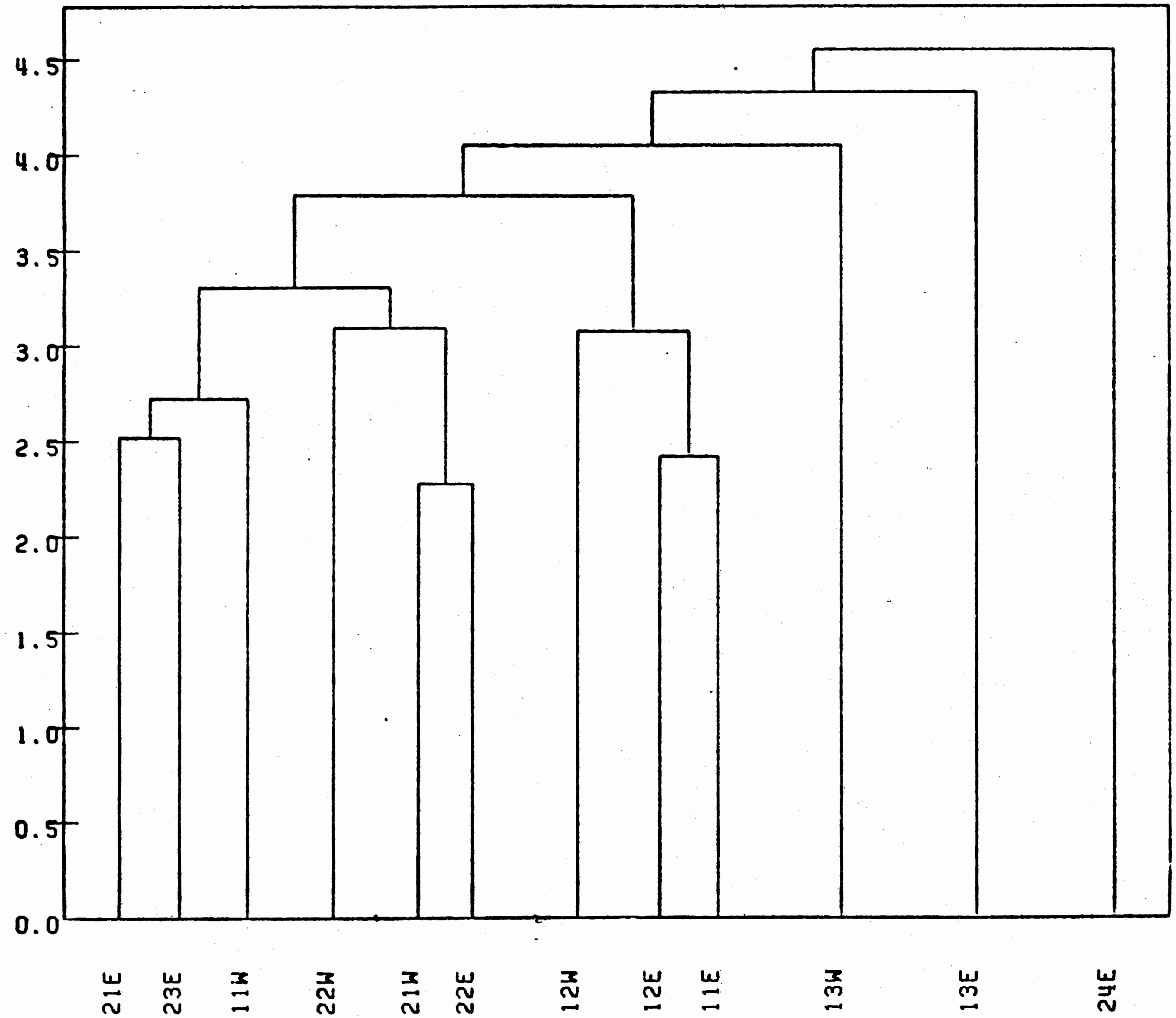


Figure 5.7. Dendogram Cluster of the Individual Pedons Using the Vegetation Percentages Cover.

sandy soils that have a buried argillic horizon, to be interpreted and managed differently from the rest of the sandy soils. This fact alone points out the necessity of onsight investigation before a final decision is reached or management begins for any soil. The buried argillic horizons in the sandy soils grouped with those of the argillic horizons of the lower positions which means that they behave similarly according to the chemical properties. Different management, as well as different production indices, have to be set for these sandy soils with a buried argillic horizon.

TABLE 5.1

SUMMARY OF THE HORIZONS CLASSIFICATION BASED ON THE PRIMARY DENDOGRAM (D = .70)

Horizon	11E	12E	13E	11W	12W	13W	21E	22E	23E	24E	21W	22W
A_1	03	03	03	03	03	03	03	03	03	03	03	03
B_1	--	--	03	--	--	01	--	--	--	03	--	--
B_2	01	01	--	01	01	--	01	01	03	01	03	03
$B_{21}t$	*02	*02	01	--	--	01	--	--	*02	04	--	*04
$B_{22}t$	*01	--	02	--	--	01	--	--	--	01	--	*04
$B_{23}t$	*02	--	03	--	--	02	--	--	--	--	--	--
$B_{24}t$	*02	--	03	--	--	02	--	--	--	--	--	--
C_1	01	01	01	01	01	--	01	01	01	--	01	01
C_2	01	01	01	01	--	--	--	--	01	--	--	--
C_3	--	--	03	01	--	--	--	--	--	--	--	--
C_4	--	--	--	01	--	--	--	--	--	--	--	--

TABLE 5.2

SUMMARY OF THE HORIZONS CLASSIFICATION BASED ON THE PRIMARY DENDOGRAM (D = .65)

Horizon	11E	12E	13E	11W	12W	13W	21E	22E	23E	24E	21W	22W
A_1	03	03	03	03	03	03	03	03	03	03	03	03
B_1	--	--	03	--	--	01	--	--	--	03	--	--
B_2	01	01	--	01	01	--	01	01	03	--	03	03
$B_{21}t$	*02	*02	01	--	--	01	--	--	*02	04	--	*04
$B_{22}t$	*01	--	02	--	--	01	--	--	--	01	--	*04
$B_{23}t$	*02	--	03	--	--	02	--	--	--	--	--	--
$B_{24}t$	*02	--	03	--	--	02	--	--	--	--	--	--
B_3	--	--	--	--	--	--	--	--	--	01	--	--
C_1	01	01	01	01	01	--	01	01	01	--	01	01
C_2	01	01	01	01	--	--	--	--	01	--	--	--
C_3	--	--	03	01	--	--	--	--	--	--	--	--
C_4	--	--	--	01	--	--	--	--	--	--	--	--

TABLE 5.3

SUMMARY OF THE HORIZONS CLASSIFICATION BASED ON THE PRIMARY DENDOGRAM (D = .62)

Horizon	11E	12E	13E	11W	12W	13W	21E	22E	23E	24E	21W	22W
A_1	06	06	06	06	06	06	06	06	06	06	06	06
B_1	--	--	06	--	--	01	--	--	--	06	--	--
B_2	01	01	--	01	01	--	01	01	06	01	06	06
$B_{21}t$	*04	*04	01	--	--	01	--	--	*03	08	--	*08
$B_{22}t$	*02	--	04	--	--	01	--	--	--	01	--	*07
$B_{23}t$	*04	--	06	--	--	04	--	--	--	--	--	--
$B_{24}t$	*04	--	05	--	--	04	--	--	--	--	--	--
C_1	01	01	01	01	01	--	01	01	01	--	01	01
C_2	01	01	01	01	--	--	--	--	01	--	--	--
C_3	--	--	06	01	--	--	--	--	--	--	--	--
C_4	--	--	--	01	--	--	--	--	--	--	--	--

TABLE 5.4

TRANSITION MATRIX FOR PEDON 13E (D = .65), AREA ONE

	01	02	03	04	05	06	07	08
01	01	01	01	00	00	00	00	00
02	00	00	01	00	00	00	00	00
03	02	00	02	00	00	00	00	00
04	00	00	00	00	00	00	00	00
05	00	00	00	00	00	00	00	00
06	00	00	00	00	00	00	00	00
07	00	00	00	00	00	00	00	00
08	00	00	00	00	00	00	00	00

CHAPTER VI

CLAY MINERALOGY OF SOME SELECTED SOILS OF THE DUNES

Abstract

Clay mineralogy of the important genetic horizons from three different slope positions of the stabilized sand dunes were studied using X-ray diffraction. The east-facing summit, toe slope, and the west-facing summit positions for both sites were used in this analysis. The X-ray diffraction patterns showed that there is no difference in the clay mineralogical composition between the two stabilized sand dunes, which suggests that both have been originated from a similar parent material. Also there is no difference noticed between the genetic horizons of one sand dune area. In all locations, illite is a dominant clay mineral in the stabilized sand dune area. Kaolinite, montmorillonite, and a random mixture of 10 + 14 Å peak are present in an appreciable amount in most of the samples. All samples appear to have a higher amount of quartz compared to those of feldspars. The surface layer of the stabilized dunes contains high amounts of mixed-layer type clays, and decreases with depth, which might be due to surface weathering activities and instability.

Introduction

Clay mineralogy of the sand dunes is an important step in identifying the weathering stages, products, and patterns during which soils have been formed. Clay minerals are the principal constituents of many fine-grained sediments, schists, and weathering products of many types of rocks. Knowing the sequence and the type of clay minerals helps identify which soils have formed in place and which have transported and deposited in another.

This work is done on the Pratt-Tivoli soil association of high sand dunes for the same reasons mentioned above. This association consists of deep sandy soils that have formed on steep sand dunes under a cover of tall and short native grasses. Sands have been reworked by wind action to form a duney sand strip. The surface layer of these soils is generally brown loamy fine sand. It is single-grained and is slightly hard when dry and friable when moist. The subsoil is yellowish-brown loamy fine sand. It has weak, granular structure and is slightly hard when dry and very friable when moist. The subsoil is generally stratified with an alternate of fine to very fine sand with some thin strata of clayey materials at different depths. The toe slope positions are associated with a well-developed argillic horizon. The summits, shoulders, and the back slopes are highly eroded and are associated with weakly-developed soil profiles. The parent material is wind-deposited sand that has been rolled and bounced from stream channels to the uplands. Pedon descriptions are listed in Appendix B.

Results and Discussion

X-ray Diffraction Analysis

X-ray diffraction patterns for the clay fractions of the A, B, and C horizons of the soils studied are shown in Tables 6.1 and 6.2.

TABLE 6.1

CLAY MINERALOGY OF THE SOILS DEVELOPED IN THE FIRST SITE OF THE SAND DUNES OF NORTH-WESTERN OKLAHOMA (Ecotone 1)

Sample No.	Location	Horizon	Depth cm.	X-ray Diffraction
	Ecot. 1			
49	East Summit	A	0-28	IKQzFx(ML)
84	" =	B1	210-260	IKQzFs(ML)
9	" =	C	390-420	IKMQzFs
	Ecot. 1			
27	Bottomland	A	0-45	IKMQzFs
97	" =	B2t	124-162	IKMQzFs
78	" =	C	190-216	IKMQzFs
	Ecot. 1			
94	West Summit	A	0-33	IKQzFs(ML)
13	" =	B1	75-151	IKMQzFs(ML)
56	" =	C	398-434	IKMQzFs

I = Illite
K = Kaolinite
M = Montmorillonite

Qz = Quarts
Fs = Feldspars
(ML) = Mixed layer clays

TABLE 6.2

CLAY MINERALOGY OF THE SOILS DEVELOPED IN THE SECOND SITES OF THE SAND DUNES OF NORTH-WESTERN OKLAHOMA (Ecotone 2)

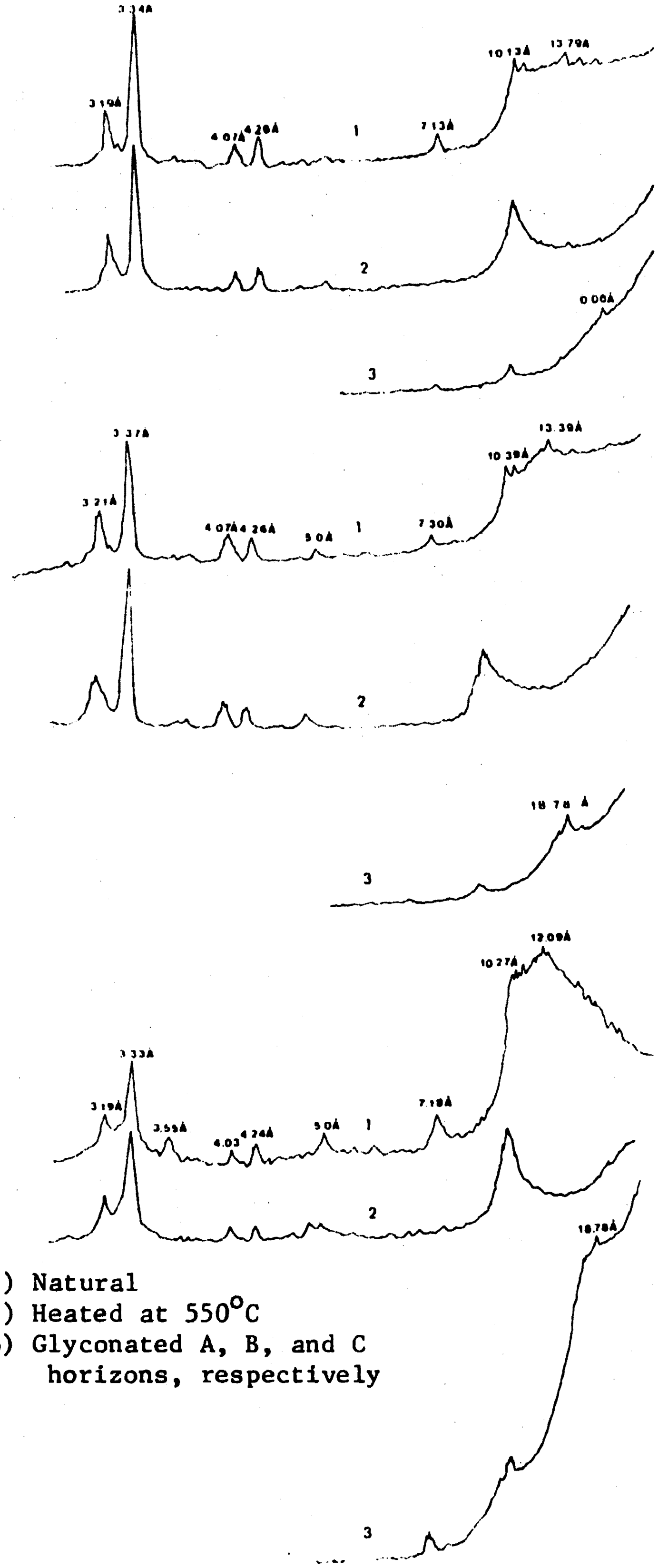
Sample No.	Location	Horizon	Depth cm.	X-ray Diffraction
	Ecot. 2			
45	East Summit	A	0-18	IKQzFs(ML)
33	" =	B1	18-48	IKMQzFs
11	" =	C	48-200	IKQzFs(ML)
	Ecot. 2			
21	Bottomland	A	0-10	IKMQzFs
83	" =	B2t	63-97	IKMQzFs
48	" =	IIB2t	131-200	IKQzFs(ML)
	Ecot. 2			
36	West Summit	A	0-10	IKQzFs(ML)
66	" =	B1	10-36	IKQzFs(ML)
4	" =	C	36-200	IKMQzFs

I = Illite
K = Kaolinite
M = Montmorillonite
Qz = Quartz
Fs = Feldspars
(ML) = Mixed layer clays

In all locations illite is a dominant clay mineral as identified by the X-ray diffractograms (Figures 6.1, 6.2, 6.3, 6.4, 6.5, and 6.6), by peaks of 10 and 5 Å. Kaolinite also is dominant in all samples as indicated by the 7.1 and 7.3 Å peaks which disappeared due to 500°C heating suggested the presence of orderly crystalline kaolinite in the clay fractions. Montmorillonite is either present independently in a random mixture with a 10 Å peak, as shown by a 12.98 Å peak for Na-montmorillonite, a 14.47 Å peak for Ca-montmorillonite expanded to 17 or 18 Å peak due to solvation with ethylene glycol; and due to the heat treatment at 500°C, it collapsed to 10 Å. This suggested the presence of interlayered 2:1 expansible clay minerals in the clay fractions of these horizons. Some horizons, especially in summit positions, show a 13.79 Å peak which indicates the presence of a random mixture of 10 + 14 Å peaks (Jackson, 1956). Also the presence of 16.66 and 20.06 Å peaks supports the presence of a random mixture of montmorillonite (Na or Ca) with a 10 Å peak of illite (Charlotte, 1961). Quartz was present in all samples in an appreciable amount as indicated by the sharp peaks of 4.26 and 3.34 Å. Feldspar was present in small amounts as supported by the presence of 3.19 and 3.20 Å peaks (Jackson, 1956 and Caroll, 1970).

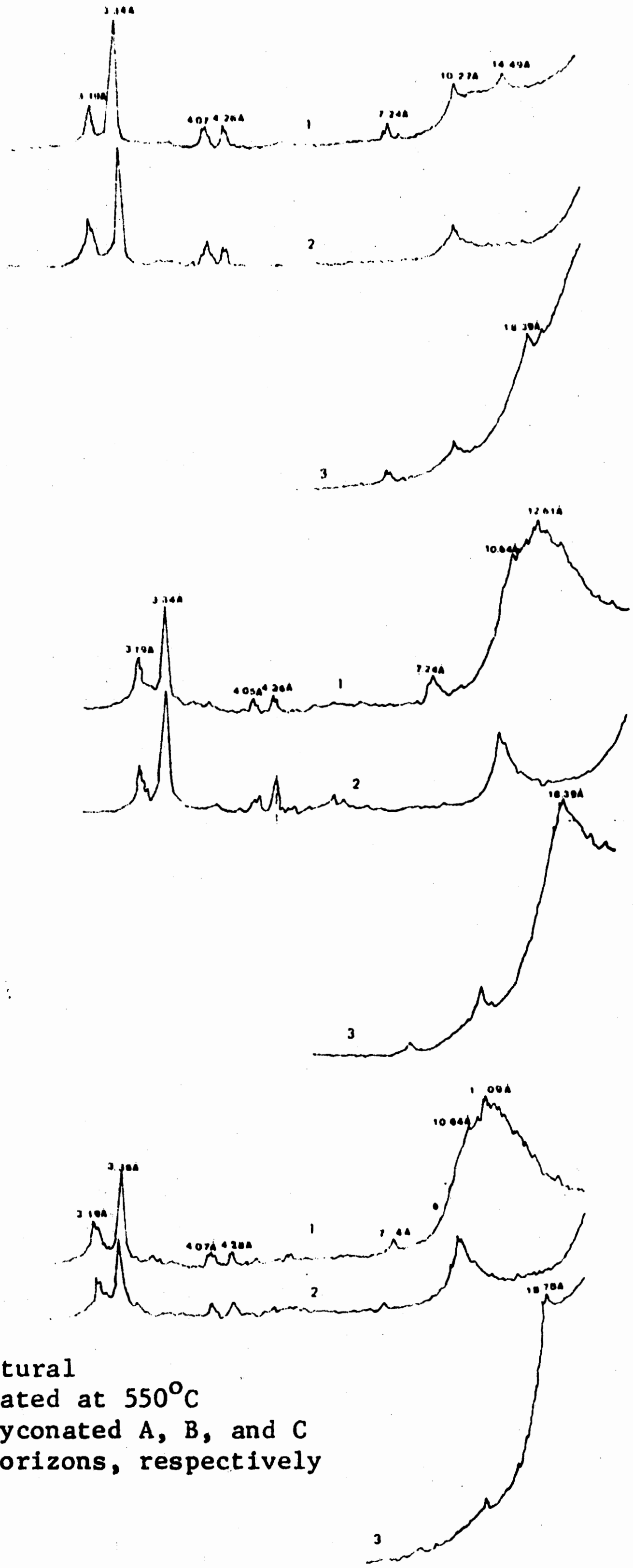
As noticed from the X-ray diffraction patterns, there is no difference in the clay mineralogy between the two sand dune areas, and seems to have originated from similar parent material. Also, there is no difference noticed between the horizons in one sand dune area.

As noticed in these results, most of the samples contain mixed-layer clay minerals, which are very common in soils and sediments. Weaver (1956) stated that from an approximation of over 6,000 sedimentary rock samples from all over the United States, ranging in age from



(1) Natural
(2) Heated at 550^{o}C
(3) Glyconated A, B, and C horizons, respectively

Figure 6.1. X-ray Diffractograms of the East Summit of Area One.



Figury 6.2. X-ray Diffractogram of the Bottomland of Area One.

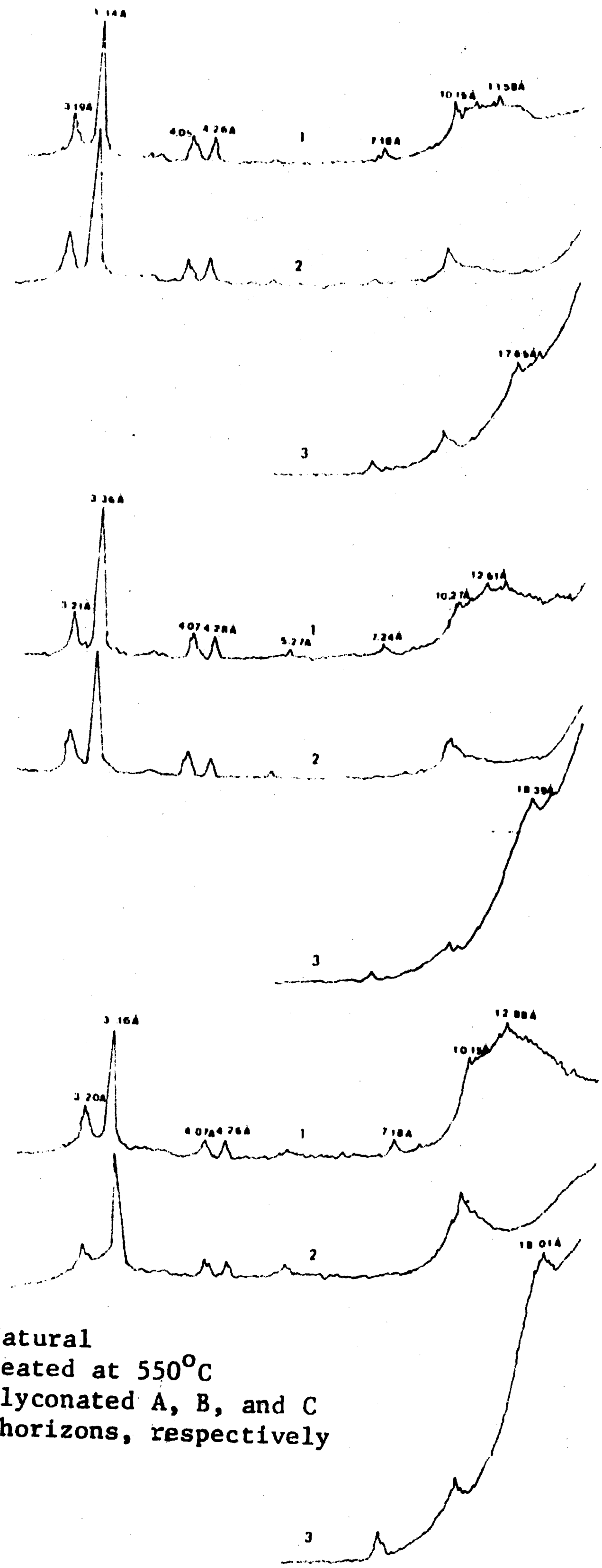


Figure 6.3. X-ray Diffractograms of the West Summit of Area One.

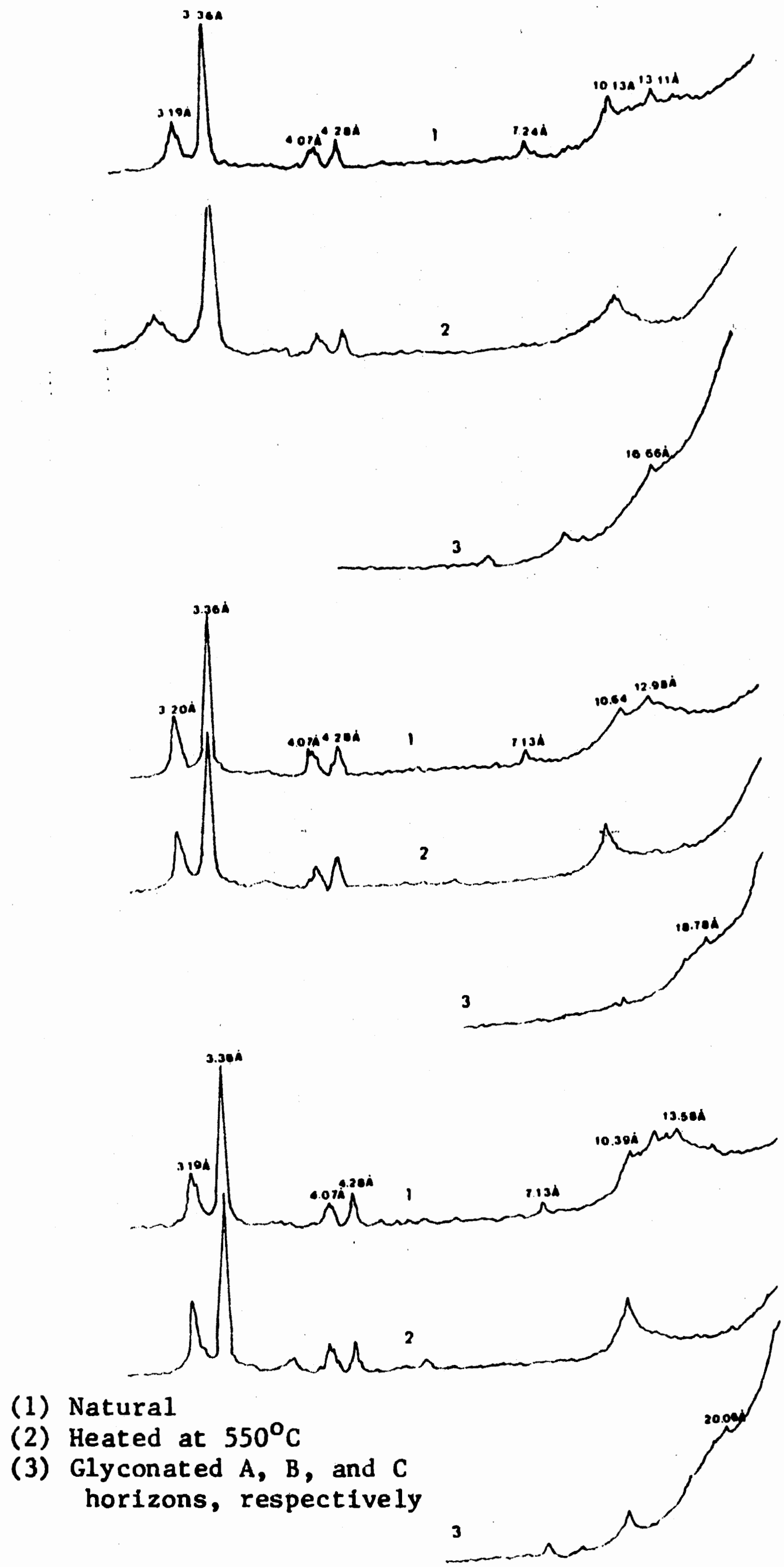
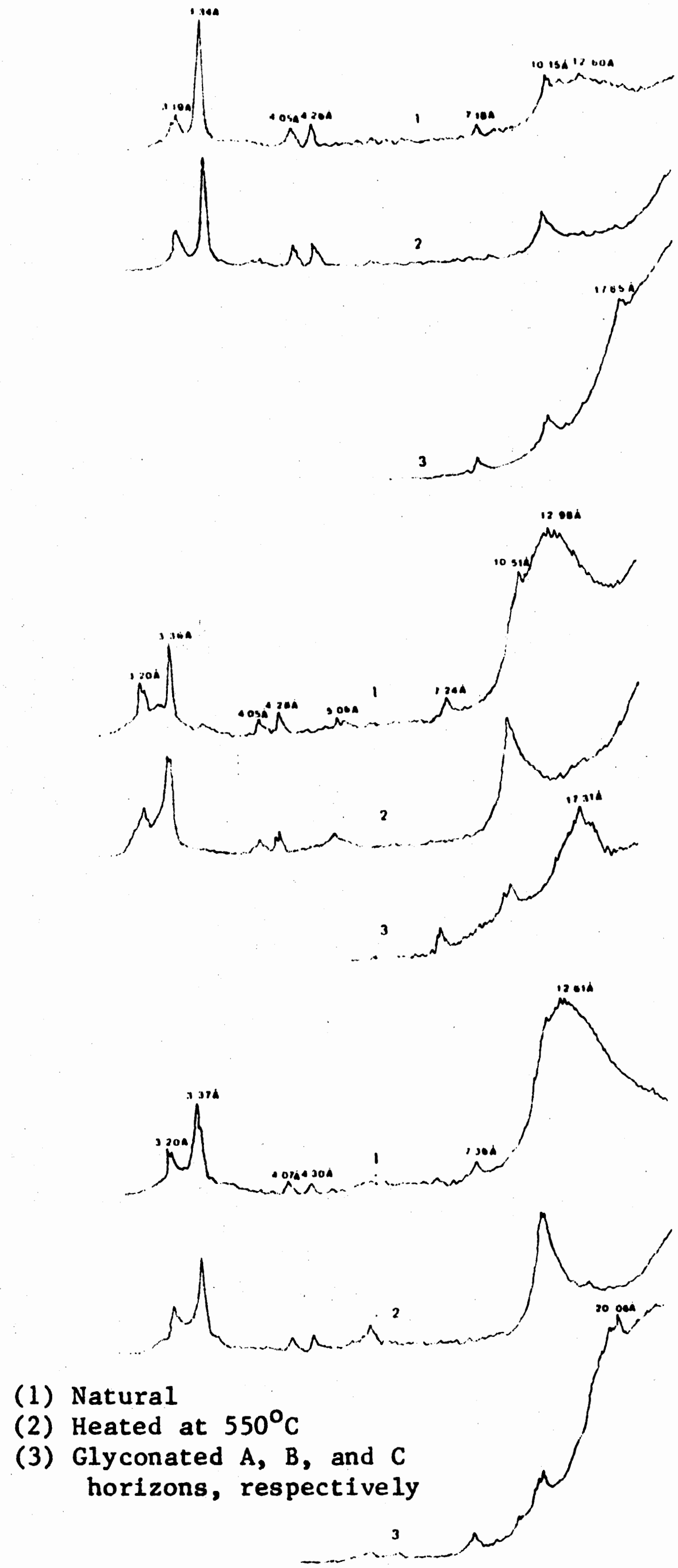
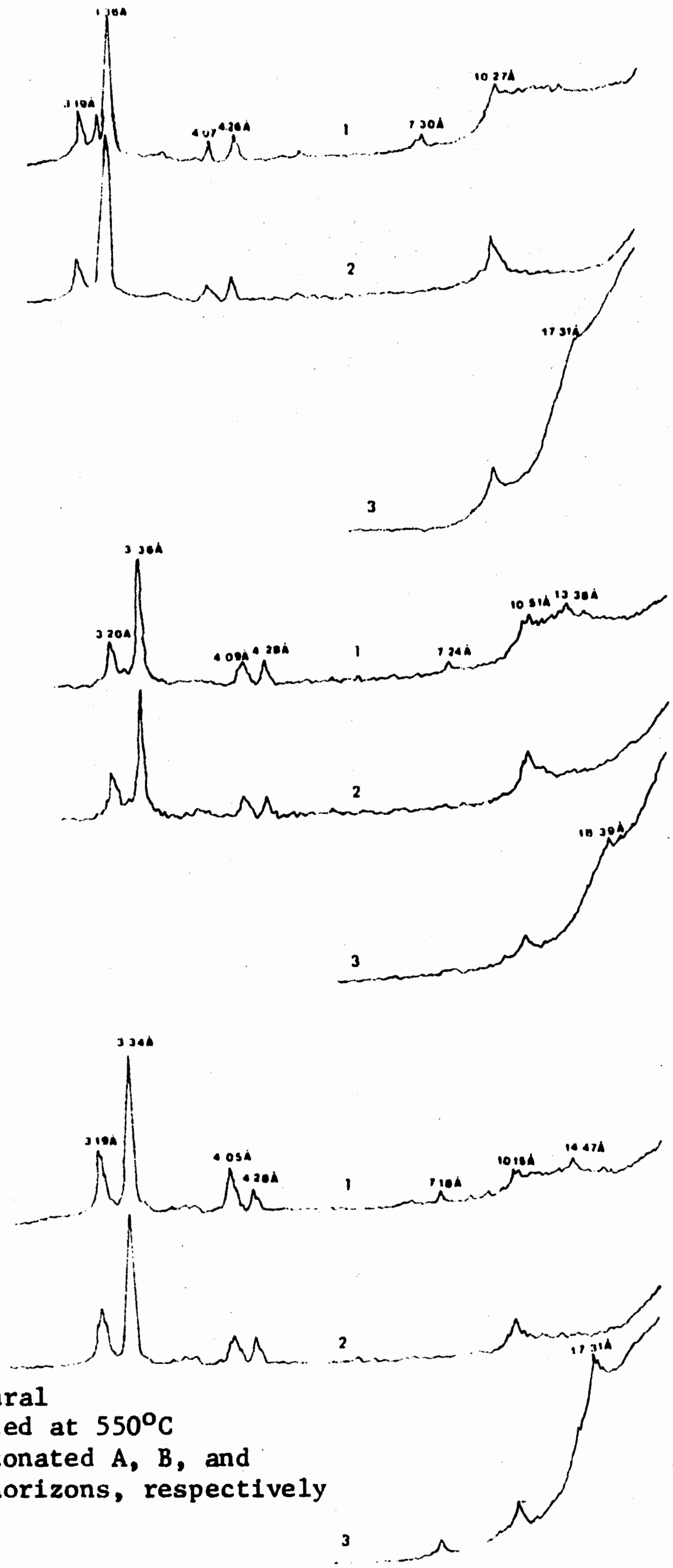


Figure 6.4. X-ray Diffractograms of East Summit of Area Two.



Figury 6.5. X-ray Diffractograms of the Bottomland of Area Two.



(1) Natural
(2) Heated at 550°C
(3) Glyconated A, B, and C horizons, respectively

Figure 6.6. X-ray Diffractograms of the West Summit of Area Two.

Cambrian to Recent, it is estimated that over 70 percent of the samples contain some variety of mixed-layer clay.

Mixed-layer clays are believed to be an adjustment to the environment in two ways, as explained by Dorothy (1970): 1) degradation as in weathering rocks and soils, and 2) diagenesis as in deposits of detrital materials.

The surface layer of Pratt-Tivoli soil samples contains mixed-layer type of clays, and decreases as noticed by depth, which might be due to surface weathering activities and instability.

CHAPTER VII

RELIEF AND ITS EFFECT ON SOIL-MOISTURE AND TEMPERATURE PROFILES WITHIN THE STABILIZED SAND DUNES

Abstract

East-west facing slopes of two sites of the stabilized sand dunes of Northwestern Oklahoma were chosen for the original purpose of this research in order to study soil-plant relationships in the sandy ecotones. Soil-moisture data, as well as soil temperature readings, were taken regularly in the same transect as the selected soil pedons for a period of seven months during 1978. Seven neutron probe tubes were installed in positions where a plant community was noticed to be sharply contrasted. Moisture readings were taken at 20 cm depth intervals to a total depth of 440 cm in each position. Using a thermocouple, soil temperature readings were taken at two depths, 15 and 50 cm, in the same positions of the neutron probe tubes.

Fluctuation of soil temperatures at 15 cm depth was greater than that of 50 cm depth. Maximum temperatures were recorded in May, June, and July at all positions. West-facing slopes were warmer than east-facing slopes by 1 to 2 degrees in both sites.

Soil moisture readings showed that maximum total moisture contents occurred in foot slope and back slope positions of both sites. Changes

in total moisture content in all positions were controlled mainly by the amount of precipitation on the area, presence of the argillic horizons, and by the intensity of lateral movement of water and run-off from higher positions.

Introduction

Due to the importance of both soil-moisture and soil-temperature and their effect on soil-plant relationships, it has been decided to gather them in an independent chapter. Temperature and moisture are important in terrestrial environments and closely interacting. They are usually considered to be the most important part of climate (Eugene, 1971). Soil-moisture is an important factor in determining the storage and transfer of heat in soil. It is also essential for plant growth and development and is the medium in which nutrients are transported. Therefore, an understanding of the status of water in the soil is of central importance in interpreting relationships between the plant and the environment of the soil (Bannister, 1978). In the system of soil classification (Soil Survey Staff, 1960 and 1967) adopted by the National Cooperative Soil Survey, January 1, 1965, soil characteristics, including soil-moisture and soil temperature, are used to differentiate the classes within the system. Climate appears to be an important parameter for characterizing soil pedons at various levels in the taxonomic scheme for Canadian Soils (Canada Soil Survey Committee, 1970).

Many papers were published concerning the microclimate of north-south-facing slopes at different areas. There is a need for more information on soil-moisture and soil-temperature of east-west facing slopes as well, especially in the sandy areas where both moisture and temperature are important factors that control soil-plant relationships.

Macyk et al. (1978) stated that there is a need for more information on temperature and moisture regimes of sloping land surfaces. This chapter deals with changes in moisture and temperature profiles as a result of changes in slope positions. Soil-moisture and temperature in sloping land is greatly influenced by the nature of soil surface, such as vegetative cover, slope degree and aspect, drainage conditions, and many others. Boul et al. (1973) discussed the importance of the slope within any geographical area and the soil properties that are commonly found to be relief-related. They are: 1) depth of solum, 2) thickness and organic matter content of the A horizon, 3) relative wetness of the profile, 4) color of the profile, 5) degree of horizon differentiation, 6) soil reaction, 7) content of soluble salts, 8) kind and degree of "pan" development, 9) temperature, and 10) character of the initial material.

Most of these properties were measured and described in different chapters of this study. Moisture and temperature data also were used in the canonical correlation technique as a separate variable to find the relationships between different plant species and soil-moisture and temperature variations.

Results and Discussion

Soil-Temperature

Variation of soil temperature was greater at the 15 cm depth than at the 50 cm depth (Figure 7.1). Soil surface temperatures were warmer in May, June, and July in almost all of the pedons studied. From August through November, soil surface temperatures dropped and the subsurface

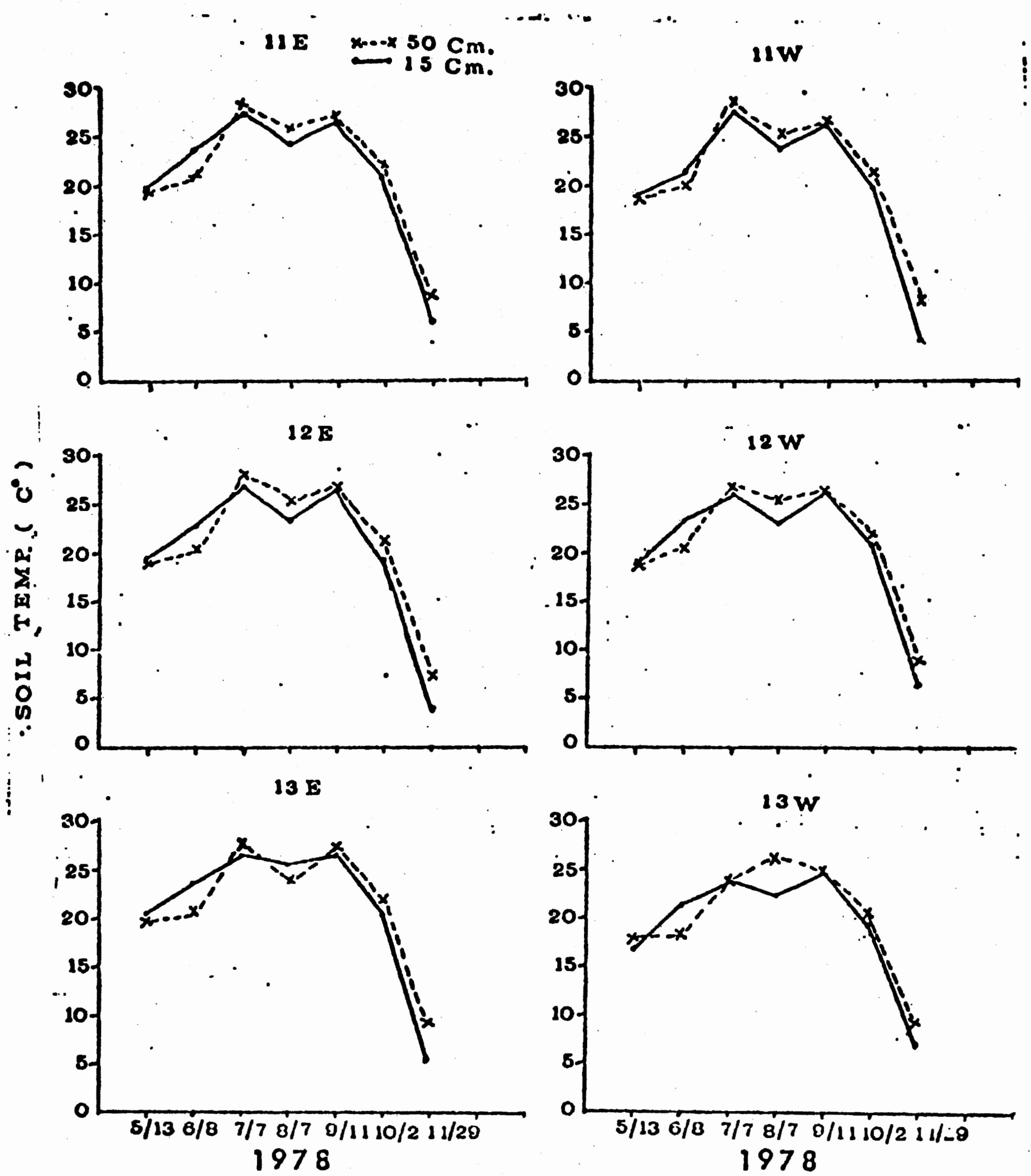


Figure 7.1. Temperature Profiles of Different Slope Positions of Area One.

temperatures were warmer than the surface. The maximum temperature was recorded during July and September in all positions. The relatively low thermal diffusivity of most soils means that the transfer of heat within soils is a slow process. This leads to the establishment of marked gradients of temperature within a soil profile. During the day, the maximum temperature was at the surface and the temperature generally decreases with depth, while during the night a reversed gradient may occur in the upper horizons of the profile. Also, the time of the year at which maximum and minimum soil temperatures are recorded varies with depth. The maximum temperatures at the surface are usually experienced in mid summer (Pannister, 1978). The deeper roots of the grasses on the stabilized sand dunes of Northwestern Oklahoma may experience annual minimum temperatures during spring and maximum temperatures during autumn. Russell (1961, quoted by Macyk et al., 1978, Canadian J. of Soil Science) stated that during the summer, heat is moving from the surface downwards and there is a regular downward temperature gradient; during the winter, heat is moving upwards and there is then a regular upward gradient. Macyk et al. (1978) stated that in the spring, heat is moving downwards from the surface and upwards from below; during autumn there is a zone above which it is moving upwards and below which it is moving downwards.

Temperatures on west-facing slopes were warmer than temperatures on the east-facing slopes (Table 7.1) by one to two degrees. Shul'gin (1957) explained such variations in his example about east-west facing slopes as the east-facing slopes having a greater expenditure of solar insolation for evaporation of dew than on west-facing slopes which were drier during the afternoon when they received more direct insolation.

TABLE 7.1

SOIL TEMPERATURE READINGS AT BOTH 15 AND 50 CM
DEPTHS OF SITE ONE OF THE DUNES

Location	11W		12W		13W		11E		12E		13E	
Depth	15 cm	50 cm	15 cm	50 cm	15 cm	50 cm	15 cm	50 cm	15 cm	50 cm	15 cm	50 cm
Date												
5/13/78	19.6	19.1	19.3	19.1	17.1	17.9	19.8	19.4	19.5	19.2	20.2	19.8
6/8/78	21.9	20.2	23.5	20.5	21.5	18.8	23.7	20.7	23.0	20.7	23.7	20.5
7/7/78	27.7	28.0	26.1	26.6	24.8	24.6	27.4	28.4	27.0	28.1	26.8	27.6
8/7/78	24.1	25.6	23.0	25.4	22.5	26.4	24.0	25.9	23.9	25.6	25.6	24.1
9/11/78	26.9	27.0	26.1	26.6	25.2	25.1	26.6	27.0	26.6	26.7	26.9	27.2
10/2/78	20.0	21.8	21.0	22.0	19.7	20.8	20.6	22.1	19.7	21.3	20.1	22.0
11/29/78	4.4	8.3	6.5	8.4	7.0	9.4	5.6	8.3	4.1	7.5	5.4	9.4

These differences in temperature could also be attributed to air movement and fluctuation in the air temperature as stated by Mueller (1968). Soil-moisture content greatly controls the temperature due to the differences in specific heat of both dry and moist soils. Another important factor is that the slopes would receive much different amounts of radiation, as should be shown by differences in temperatures. The differences found will depend upon the time of the day that the readings are taken (Shaw and Buchele, 1957). Type and amount of vegetative cover, also have a great effect on temperature differences between the different slope positions. Temperatures under shrubs are consistently about $1^{o}C$ higher than under grass from January to mid-June (Toogood, 1979).

Soil-Moisture

The total moisture content in all positions of the two sites were highest in early June and then decreased during the rest of the season with a slight increase in mid-October (Figure 7.2). The moisture content changes with the changes in precipitation. As reported by Rhoades et al. (1964), forage production on a range site in the semiarid southern Great Plains usually depends upon available soil moisture. In turn, available soil moisture depends upon: 1) intensity, duration, and frequency of precipitation; 2) water intake characteristics; 3) water retention and flow patterns within the soil profile; and 4) evaporation and transpiration characteristics of the soil surface and living vegetation.

The highest amount of precipitation was recorded in May followed by other showers in September. At Site 1, the highest total moisture

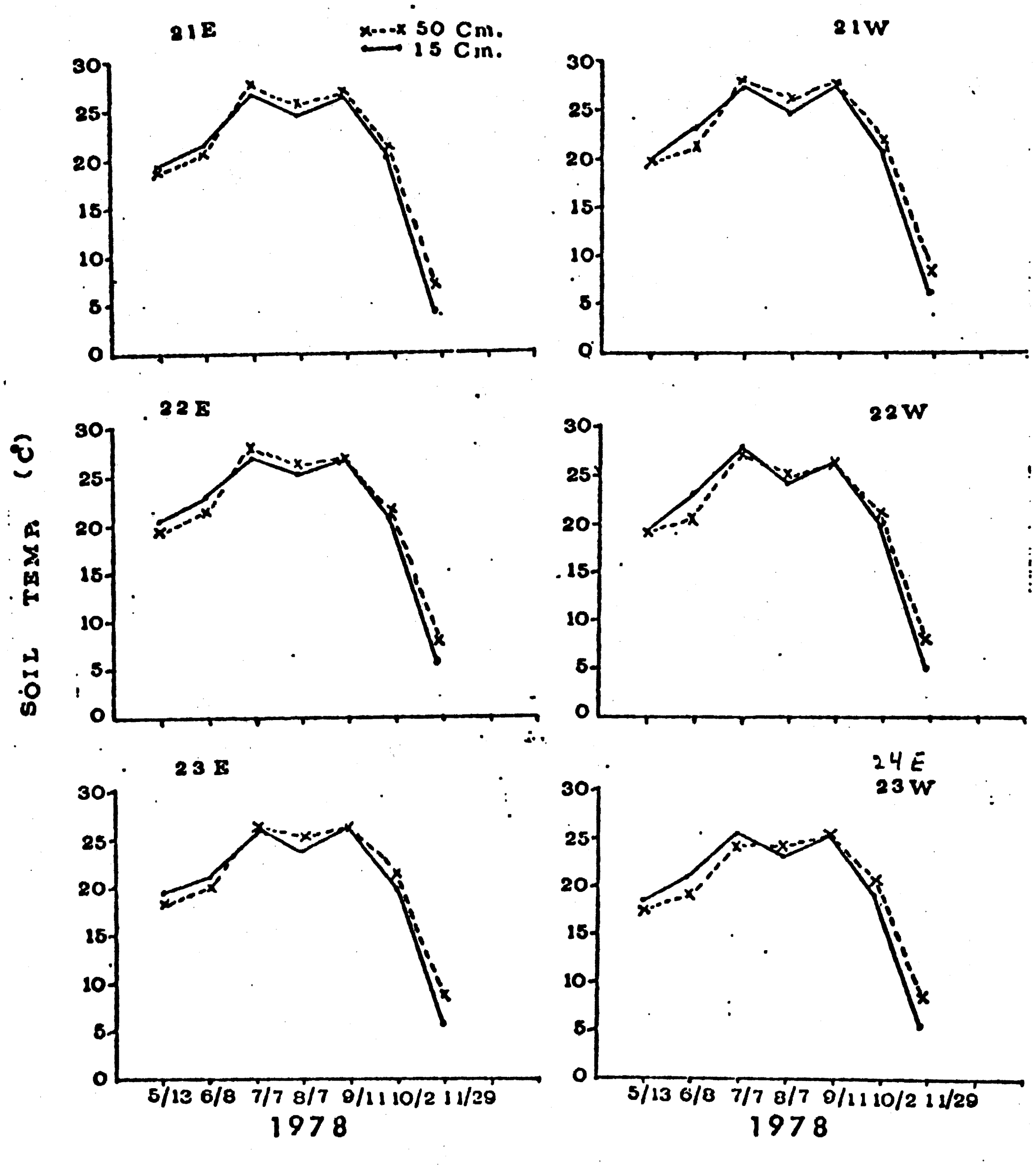


Figure 7.2. Temperature Profiles of Different Slope Positions of Area Two.

content was in the foot slope of the east-facing slope (Tube 5), followed by the back slope of the west-facing slope (Tube 2). The summit and the shoulder positions of the east-facing slope are the driest positions of the east-facing slope are the driest positions in the transect (Tubes 6 and 7). This is mainly due to the absence of the buried argillic horizon in these positions, which exhibits a high water-holding capacity. There are no significant differences between the west-facing summit and the toe slope positions (Tubes 1 and 4), which both have an argillic horizon.

At Site 2, the highest total moisture content was in the back slope of the west-facing slope (Tube 9). The second highest total moisture content was in the back slope of the east-facing slope (Tube 13). The buried argillic horizon is present in the east-facing slope positions of Site 2, which has influenced the total moisture content in the east-facing summit. The toe slope position would be expected to have a higher total moisture content, as reported elsewhere (Macyk et al., 1978), if the intensity of precipitation was higher, as an average rainfall of 19 inches per year. In that area, it is not quite enough to deposit the water in the toe slope positions by lateral movement and run off from higher positions.

Changes in moisture content with depth are controlled by the presence or absence of argillic horizon and the nature of the stratification with the profile. As shown in Figures 7.3 and 7.4, a sharp increase in moisture content occurs at the depths where the argillic horizon starts. In fact, the sharp changes in the plant communities on the surface are a reflection of the changes in the configuration of the argillic horizon beneath the surface due to changes in soil water-holding capacity. Roots

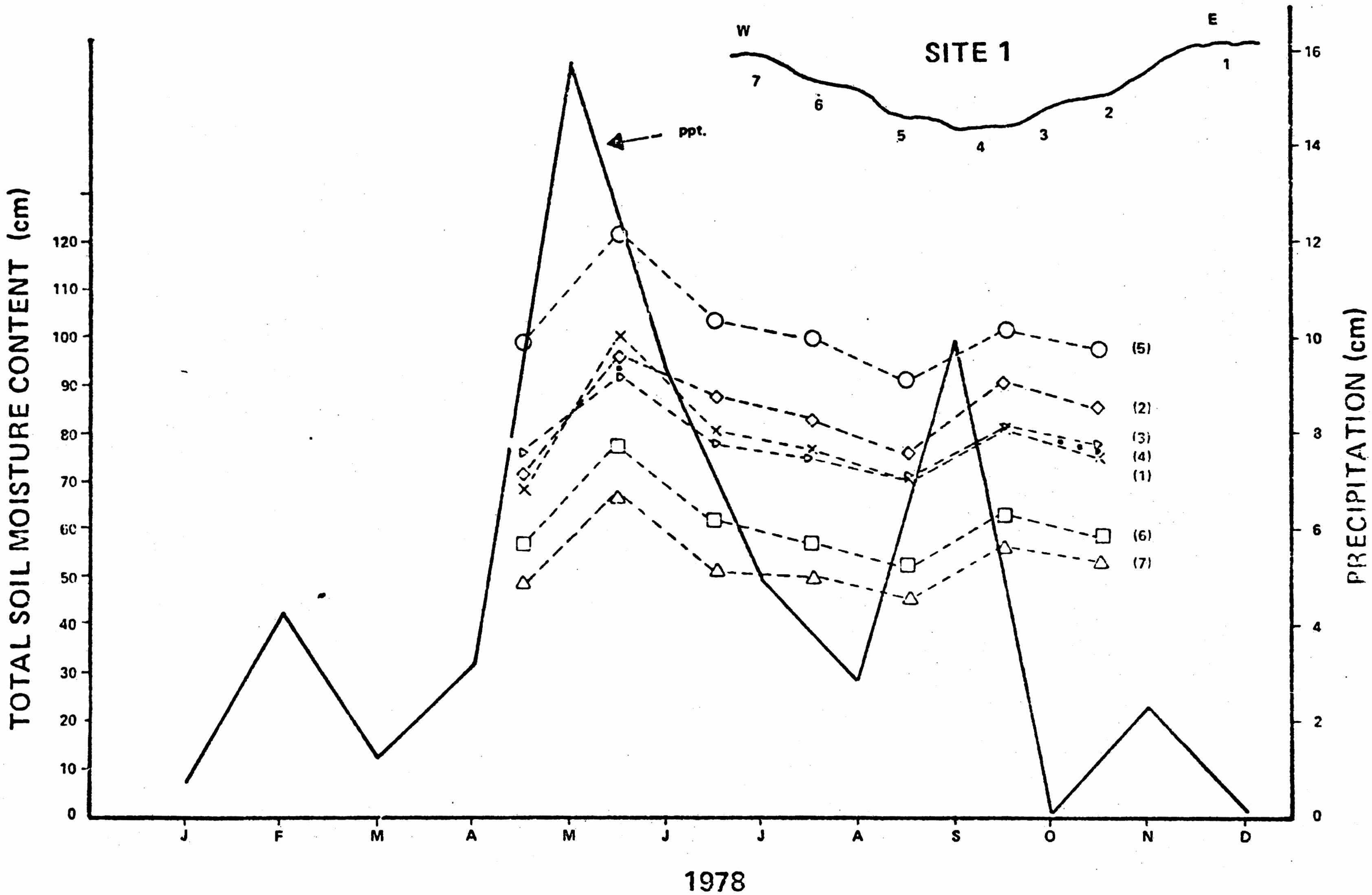


Figure 7.3. Total Moisture Content Pattern at Different Slope Positions and Precipitation of Area One.

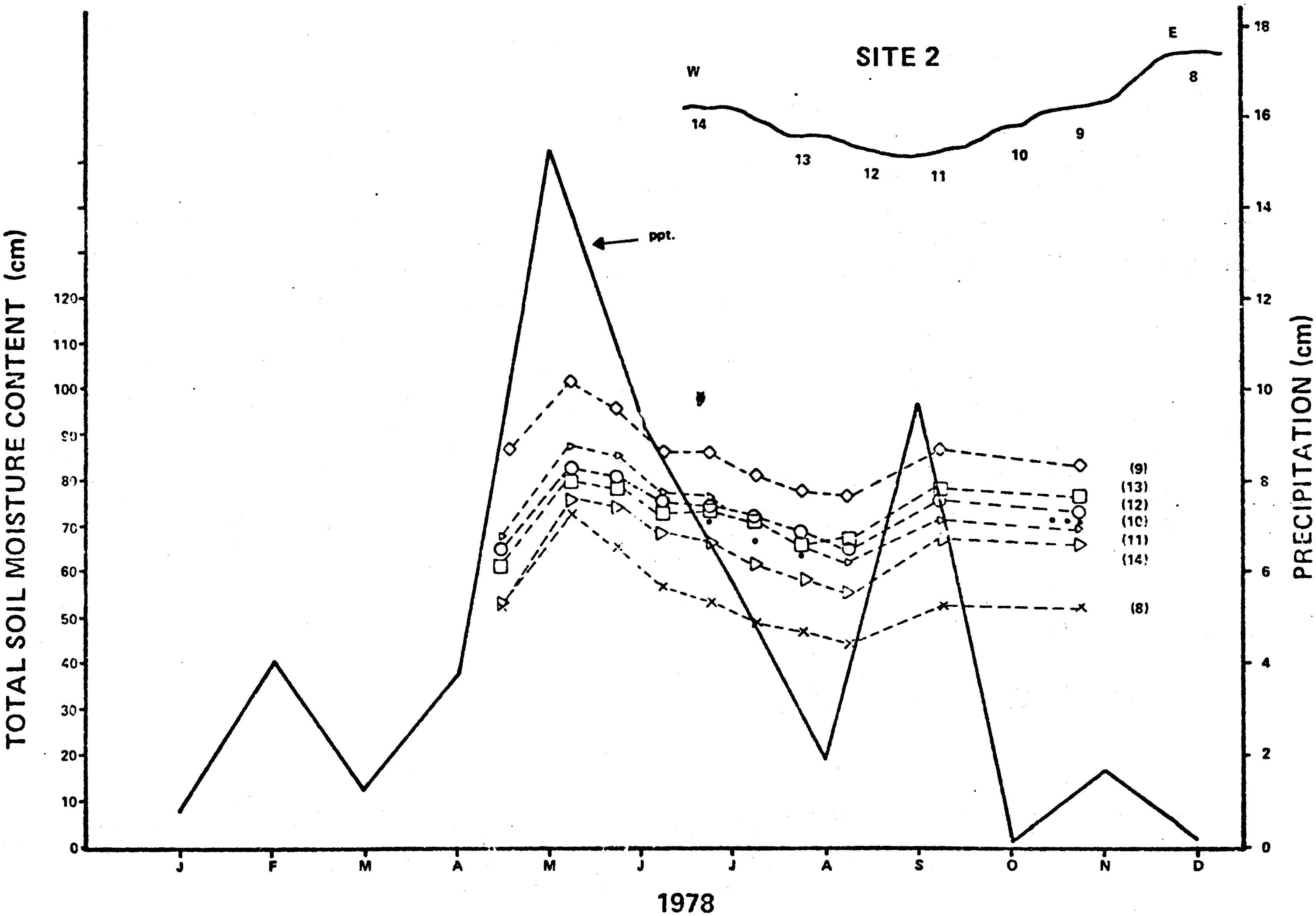


Figure 7.4. Total Moisture Content Pattern at Different Slope Positions and Precipitation of Area Two.

of prairie plants are capable of extending their roots very deep in order to reach such a horizon, especially in the places where the argillic horizon is deep. For the same soil type, Tomanek (1957) found that roots of prairie plants extended deeply into the permeable, loessial soil at Atwood. Most of the roots reached depths of 9 to 18 feet and grass roots 6 to 10 feet.

As shown in the block diagrams of both sites, the configuration of the argillic horizon changes abruptly from one position to another. It is deep and thin in some slope positions and shallow and thick in others. These differences resulted in an abrupt change in the soil water-holding capacity, cation exchange capacity, percent clay content, and many other physical and chemical properties that are related to the argillic horizon. All these changes cause a sharp variation in the existence and the distribution of the different plant communities on the surface.

Summary and Conclusion

On the east-west facing slopes of the stabilized sand dunes of Northwestern Oklahoma, soil-moisture and soil-temperature profiles were monitered very closely to show the influence of relief on the most important soil environmental factors. As a result of this study, we can conclude that:

1) Fluctuation of soil temperature at 15 cm depth is greater than that at 50 cm depth.

2) West-facing slopes are warmer than east-facing slopes by 1 to $2^{o}C$ in both sites.

3) Soil-moisture readings showed that maximum total moisture content tents occurred in the foot slope and the back slope positions in both

3) Soil-moisture readings showed that maximum total moisture contents occurred in the foot slope and the back slope positions in both areas.

4) Changes in the moisture content in all positions are controlled mainly by the amount of precipitation on the area, presence and configuration of the argillic horizon, and by the intensity of lateral movement and run-off from higher slope positions.

5) The sharp variations in the plant communities might be due, collectively, to the abrupt changes of the chemical and physical properties that are related to the argillic horizon, mainly soil water-holding capacity.

TABLE 7.2

SOIL TEMPERATURE READINGS AT BOTH 15 AND 50 CM
DEPTHS OF SITE TWO OF THE DUNES

Location	21W		22W		21E		22E		23E		24E	
Depth	15 cm	50 cm	15 cm	50 cm	15 cm	50 cm	15 cm	50 cm	15 cm	50 cm	15 cm	50 cm
Date												
5/17/78	14.5	19.8	19.4	19.4	19.9	19.4	20.2	19.8	19.8	18.8	18.6	17.5
6/9/78	23.1	21.2	23.2	20.5	21.7	21.2	22.8	21.4	21.2	20.1	21.9	19.2
7/7/78	27.1	27.9	27.6	27.0	27.0	28.3	27.0	28.1	26.1	26.5	25.3	24.9
8/7/78	24.7	26.0	24.6	25.0	25.0	26.1	25.5	26.3	24.2	25.4	23.6	24.2
9/11/78	27.0	27.4	26.8	26.4	26.8	27.2	27.1	27.1	26.5	26.5	25.7	25.6
10/2/78	20.6	21.6	20.0	21.2	20.6	21.7	20.6	21.9	20.0	21.6	19.5	20.8
11/29/78	5.9	7.6	5.0	8.4	4.9	7.4	5.6	7.7	5.1	8.2	5.9	8.5

TABLE 7.3

TOTAL MOISTURE CONTENT IN CM OF WATER PER 440
CM DEPTH OF SOIL IN BOTH AREAS

Location	May	June	July	Aug.	Sept.	Oct.	Nov.
11E	69.73	100.55	84.21	77.57	70.48	81.61	75.54
12E	71.49	97.27	88.34	83.75	75.72	91.28	85.16
13E	76.70	93.03	79.19	76.15	72.80	82.71	77.43
11W	49.70	67.74	51.08	50.51	45.79	56.93	54.33
12W	57.10	77.64	62.08	57.68	52.47	64.10	59.45
21E	52.78	73.25	57.16	49.42	44.80	53.24	52.65
22E	85.00	100.91	86.64	80.69	76.11	87.00	84.03
23E	64.20	77.31	68.53	67.07	63.41	74.11	71.42
24E	68.06	88.05	77.51	70.09	62.56	72.35	69.90
21W	53.70	75.27	68.90	62.20	55.84	67.83	65.89
22W	61.64	79.97	73.98	70.74	67.18	78.22	76.19

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APPENDICES

APPENDIX A

CHEMICAL ANALYSES

TABLE 1

CHEMICAL ANALYSIS FOR 11E

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	28	75	160	157
pH	5.6	6.8	7.7	7.5
O.M.%	3.29	.95	.86	.86
Ca*	1.30	1.60	12.67	4.76
Mg*	.69	1.08	3.53	1.26
K*	.32	.31	.45	.23
Na*	.41	.13	.43	.15
C.E.C.*	4.31	3.78	13.22	3.86
Clay%	7.50	4.37	10.97	3.38
Vcs%	.19	.08	.12	.20
Cs%	3.26	4.14	2.51	7.03
Ms%	42.93	54.07	13.66	41.87
Fs%	38.30	30.55	26.20	36.58
Vfs%	6.64	4.87	14.10	7.81
Quartz%	85.83	82.81	77.77	87.69
Feldspars%	14.17	17.19	22.23	12.31

*meq/100 gm of soil

TABLE 2

CHEMICAL ANALYSIS FOR 12E

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	37	47	37	101
pH	6.2	7.2	8.0	8.3
O.M.%	3.75	1.10	1.16	.56
Ca*	1.43	5.87	13.56	2.54
Mg*	.99	1.33	2.42	1.0
K*	.35	.30	.31	.22
Na*	.13	.22	.44	.39
C.E.C.*	4.32	5.03	7.17	4.38
Clay%	6.87	4.37	8.75	4.41
Vcs %	.16	.13	.13	.02
Cs %	2.87	1.89	2.0	1.62
Ms%	50.33	38.99	21.38	43.86
Fs%	29.61	45.34	30.03	34.89
Vfs%	7.91	8.04	15.13	12.05
Quartz %	87.63	86.30	79.30	87.36
Feldspars %	12.37	13.70	20.70	12.64

*meq/100 gm of soil

TABLE 3

CHEMICAL ANALYSIS FOR 13E

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	30	29	185	174
pH	6.8	7.3	7.0	7.2
O.M.%	3.44	2.71	2.15	.53
Ca*	2.11	3.63	7.35	3.98
Mg*	1.16	1.42	2.61	1.56
K*	.33	.37	.41	.26
Na*	.18	.20	.35	.43
C.E.C.*	5.28	6.26	11.31	6.51
Clay %	3.75	8.75	13.16	4.89
Vcs %	.15	.18	.07	.07
Cs %	2.04	2.62	2.31	.34
Ms %	24.44	23.53	23.35	23.44
Fs %	49.89	49.95	34.05	43.94
Vfs %	10.73	7.77	14.54	14.26
Quartz%	77.18	80.31	78.64	86.07
Feldspars%	22.82	19.69	21.36	13.93

*meq/100 gm of soil

TABLE 4

CHEMICAL ANALYSIS FOR 11W

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	33	42	-----	360
pH	6.4	7.0	-----	7.9
O.M. %	3.03	1.21	-----	1.72
Ca*	1.38	1.51	-----	7.0
Mg*	.73	.95	-----	1.26
K*	.30	.27	-----	.22
Na*	.11	.19	-----	.34
C.E.C.*	3.24	3.45	-----	4.18
Clay%	4.37	4.37	-----	6.02
Vcs%	.03	0.0	-----	.28
Cs%	.94	1.59	-----	1.96
Ms%	42.42	37.89	-----	48.07
Fs%	43.52	48.79	-----	34.82
Vfs%	6.44	3.71	-----	7.30
Quartz%	85.50	89.16	-----	84.42
Feldspars%	14.50	10.84	-----	15.58

*meq/100 gm of soil

TABLE 5

CHEMICAL ANALYSIS FOR 12W

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	36	55	-----	109
pH	6.8	7.4	-----	7.4
O.M.%	2.83	1.27	-----	.78
Ca*	1.21	1.68	-----	1.16
Mg*	.90	1.03	-----	.86
K*	.30	.27	-----	.27
Na*	0.35	.10	-----	.39
C.E.C.*	3.47	3.67	-----	3.36
Clay%	3.75	3.75	-----	5.0
Vcs %	.10	.03	-----	.10
Cs%	1.62	2.08	-----	3.10
Ms%	48.57	37.43	-----	56.49
Fs%	34.65	49.14	-----	25.88
Vfs%	7.62	6.08	-----	6.47
Quartz %	87.33	84.83	-----	85.16
Feldspars %	12.67	15.17	-----	14.84

*meq/100 gm of soil

TABLE 6

CHEMICAL ANALYSIS FOR 13W

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	45	54	117	-----
pH	6.5	7.2	7.7	-----
O.M.%	4.50	.75	.89	-----
Ca*	1.38	1.64	7.47	-----
Mg*	.60	.56	2.28	-----
K*	.31	.31	.36	-----
Na*	.39	.27	.27	-----
C.E.C.*	3.58	4.42	10.15	-----
Clay%	5.0	4.37	10.20	-----
Vcs%	.11	.63	.17	-----
Cs%	3.0	6.19	5.54	-----
Ms%	47.10	57.33	32.99	-----
Fs%	32.09	24.97	31.80	-----
Vfs%	8.78	5.61	9.14	-----
Quartz%	85.50	84.99	84.54	-----
Feldspars%	14.50	15.01	15.46	-----

*meq/100 gm of soil

TABLE 7

CHEMICAL ANALYSIS FOR 21E

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	18	30	-----	152
pH	6.1	6.9	-----	7.3
O.M.%	3.75	1.90	-----	.34
Ca*	1.25	.95	-----	.73
Mg*	.75	.95	-----	1.07
K*	.31	.25	-----	.21
Na*	.33	.41	-----	.39
C.E.C.*	3.67	3.36	-----	3.36
Clay%	4.37	4.37	-----	3.12
Vcs%	.03	.13	-----	0.0
Cs%	4.94	4.62	-----	6.07
Ms%	49.09	56.89	-----	59.34
Fs%	17.91	26.22	-----	24.84
Vfs%	5.40	5.29	-----	5.70
Quartz%	87.94	82.16	-----	86.33
Feldspars%	12.01	16.84	-----	13.67

*meq/100 gm of soil

TABLE 8

CHEMICAL ANALYSIS FOR 22E

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	10	33	-----	157
pH	6.4	6.7	-----	7.3
O.M.%	4.85	1.27	-----	.69
Ca*	1.64	1.99	-----	.95
Mg*	1.04	1.13	-----	.78
K*	.31	.23	-----	.21
Na*	.35	.22	-----	.32
C.E.C.*	3.92	3.41	-----	3.74
Clay%	6.25	5.0	-----	3.75
Vcs%	.05	.10	-----	.08
Cs%	4.77	4.85	-----	6.68
Ms%	47.83	55.31	-----	56.02
Fs%	28.66	27.74	-----	25.52
Vfs%	6.59	5.67	-----	5.48
Quartz%	86.66	86.33	-----	90.0
Feldspars%	13.34	13.67	-----	10.0

*meq/100 gm of soil

TABLE 9

CHEMICAL ANALYSIS FOR 23E

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	15	42	25	143
pH	6.6	6.7	7.1	7.2
O.M.%	3.99	4.50	2.12	.59
Ca*	1.77	1.47	17.19	1.35
Mg*	.69	.64	4.58	1.07
K*	.38	.25	.44	.24
Na*	.27	.22	.10	.38
C.E.C.*	5.18	3.30	22.46	3.49
Clay%	5.63	3.75	26.25	5.93
Vcs %	.11	.70	.05	.40
Cs %	6.18	5.67	1.05	7.49
Ms %	50.05	48.64	7.95	48.87
Fs %	22.71	34.37	22.18	31.12
Vfs %	5.53	5.03	13.68	4.78
Quartz %	90.50	88.50	84.66	89.73
Feldspars %	9.50	11.50	15.34	10.27

*meq/100 gm of soil

TABLE 10

CHEMICAL ANALYSIS FOR 24E

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	10	122	68	-----
pH	6.7	6.7	6.5	-----
O.M.%	4.73	2.0	2.25	-----
Ca*	2.20	3.29	11.79	-----
Mg*	1.12	1.41	4.75	-----
K*	.43	.33	.59	-----
Na*	.27	.33	.31	-----
C.E.C.*	5.16	6.0	16.74	-----
Clay%	4.37	7.55	17.82	-----
Vcs%	.19	.34	.77	-----
Cs%	6.24	5.29	4.17	-----
Ms%	37.92	46.57	20.68	-----
Fs%	33.87	22.93	23.36	-----
Vfs%	7.62	6.06	12.12	-----
Quartz%	89.49	87.05	77.75	-----
Feldspars%	10.51	12.95	22.25	-----

*meq/100 gm of soil

TABLE 11

CHEMICAL ANALYSIS FOR 21W

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	10	26	------	164
pH	6.6	6.6	------	7.4
O.M.%	3.38	2.48	------	.82
Ca*	1.73	1.38	------	2.03
Mg*	.77	.86	------	1.12
K*	.35	.36	------	.26
Na*	.35	.14	------	.39
C.E.C. *	4.25	3.89	------	4.08
Clay%	4.37	6.87	------	5.0
VCS %	.15	.11	------	.20
CS %	2.98	2.64	------	3.19
MS %	53.73	58.90	------	58.96
Fs %	27.45	23.05	------	24.51
Vfs %	6.11	6.10	------	6.98
Quartz %	89.10	88.33	------	87.0
Feldspars %	10.90	11.67	------	13.0

*meq/100 gm of soil

TABLE 12

CHEMICAL ANALYSIS FOR 22W

Soil Property	Weighted Genetic Horizons			
	A	B	Bt	C
Thickness (cm)	15	82	41	55
pH	6.6	7.1	7.0	7.3
O.M.%	4.91	2.83	1.90	.52
Ca*	2.07	.90	15.40	1.81
Mg*	1.08	.52	5.56	1.08
K*	.36	.27	.81	.31
Na*	.24	.56	.20	.43
C.E.C.*	4.73	3.47	20.23	4.51
Clay%	5.0	5.0	26.34	5.0
VCS%	.22	.05	.03	.19
CS%	3.39	2.79	.36	2.99
Ms%	40.68	56.34	3.25	48.58
Fs%	37.14	26.03	17.73	31.31
Vfs%	7.69	7.28	23.24	7.47
Quartz%	86.75	91.16	64.18	85.16
Feldspars%	13.25	8.84	35.82	14.84

*meq/100 gm of soil

APPENDIX B

PEDON DESCRIPTIONS

Ecotone 1E

Pedon 1

A 5% slope, concave, summit position (somewhat exc. very-well drained). From a surface to a depth of three meters and seven cm is a layer of sand and loamy sand, then a 40 cm thick clay layer, with alternative stratification of fine sand (loamy sand) and clay layers to a depth of 15 feet.

A1 - 0-28 cm; Dark brown (10YR 3/3 M); loamy sand; medium weak granular; slightly hard, non-plastic, non-sticky; common coarse and fine roots; few fine pores; neutral; gradual smooth boundary.

B2 - 28-107 cm; brown (7.5 YR 4/4); loamy sand; coarse weak subangular blocky breaks to single grains; friable, non-sticky, non-plastic; common medium and fine roots; few fine pores; very fine black bodies; gradual smooth boundary.

C1 - 107-200 cm; brown (7.5YR 4/4); loamy sand; coarse weak subangular blocky breaks to single grains; friable, non-sticky, non-plastic; common medium and fine roots; few fine pores; very few fine black bodies; iron coatings and/or fine clay.

Special Comments: Starting early stages of lamela in the C horizon with a stratum per inch with variable thickness of strata. $CaCO_3$ concentration present at a depth of 260 cm. A buried horizon present at 285 cm. Wind erosion is active in this position. At a depth of three meters and seven cm, a 40 cm thick clay layer is present followed by coarse sand, 10 cm thick clay layer, 15 cm thick fine sand, 10 cm clay, 7 cm fine sand, and then a clay layer at a depth of 4 meters.

Pedon 2

A 9% slope, concave, shoulder position, 4.5 meters west of Pedon 1, wind erosion, somewhat exc. drained.

A1 - 0-37 cm; Dark brown (7.5YR 4/2); loamy sand; weak, medium granular structure; slightly hard, non-plastic, non-sticky; common, fine and medium roots; medium, fine pores; gradual wavy boundary.

B2 - 37-84 cm; Brown (7.5YR 4/4); loamy sand; weak coarse prismatic breaking to subangular and angular blocky structure; friable, non-sticky, non-plastic; common, medium, and fine roots; few fine pores; diffused, smooth boundary.

C1 - 84-132 cm; Dark brown (7.5YR 5/4); loamy sand; very weak prismatic breaking to subangular blocky structure; friable, non-sticky, non-plastic; few to moderate fine and medium roots; few fine pores.

C2 - 132-185 cm; Light brown (7.5YR 6/4); loamy sand; very weak prismatic breaking to subangular blocky structure; friable, non-sticky, non-plastic; few to moderate fine and medium roots; few fine pores.

Special Comments: At a depth of 213 cm, a layer of sand (loamy sand) followed by a ten cm thick clay layer at a depth of 213 cm to 223 cm, then a layer of sand to a depth of 300 cm; from a depth of 300 cm to 350 cm a layer of clay is present followed by a layer of sand from 350 cm to 426 to 435 cm and then sand to a depth of 457 cm.

Pedon 3

3% slope, concave, bottomland.

A1 ----- 0-30 cm; very dark, grayish brown (10YR 3/2); sandy loam; weak, medium, granular and subangular blocky structure; slightly hard, non-sticky, non-plastic; common fine and medium roots; medium, fine pores; diffused, smooth boundary.

B1 ----- 30-59 cm; Dark brown (10YR 3/3); sandy loam; weak coarse, and medium, subangular blocky structure; slightly hard, slightly sticky, non-plastic; moderate, medium, and fine pores; thin, patchy clay films; clear, wavy boundary.

B21t --- 59-108 cm; strong brown (7.5YR 4/6); sandy clay loam; coarse, strong, prismatic breaking to subangular and angular blocky structure; slightly firm, slightly plastic, slightly sticky; few fine and medium roots; few fine pores; organic matter and iron coatings; clay films; clear wavy boundary.

B22t --- 108-158 cm; Strong brown (7.5YR 5/6); sandy clay loam; strong, coarse subangular blocky and APK structure; firm and extremely hard when dry, slightly sticky, slightly plastic; very few fine roots; very few fine pores; coarse common distinct concentration of mottles (5 YR 5/8); clay films.

B23t --- 158-203 cm; bright, reddish-red (5YR 5/6); sandy loam; weak, coarse, subangular blocky structure; slightly hard, non-plastic, non-sticky; very few fine roots; very few fine pores.

IIB24t - 203-244 cm; reddish-brown (5YR 5/4); very fine sandy loam; weak coarse subangular blocky structure; slightly hard, non-plastic, non-sticky; very few fine roots; few mottles (5YR 5/8) with strata of coarse sandy loam (5YR 5/6); abrupt wavy boundary.

IIC1 --- 244-337 cm; stratified (7.5YR 5/4, 7.5YR 6/4, and 10YR 6/3); very fine silt; very fine sand; and silt.

IIC2 --- 337-398 cm; stratified and similar to IIC1, except slightly more grayish in color.

IIC3 --- 398-416 cm; reddish-brown (5YR 5/4); clay loam.

IIC4 --- 416-434 cm; stratified, very fine silt and very fine sand (not sampled). The position of the pedon is in a trapped drainage, sedimentation by wind and/or water. Below it IIB2t.

Special Comments: Streaking in B22t, the prisms are coated with OM, especially in B22t and three different materials matrix strip and iron-coated mottles at the depth of the B22t, oxidation conditions prevailing.

Ecotone 1W

Pedon 1

A 2% slope, convex, summit position.

A -- 0-33 cm; Dark brown (10YR 4/3); loamy sand; weak fine granular and weak moderate subangular blocky structure; soft, non-plastic, non-sticky; common fine roots; medium, fine pores; gradual smooth boundary.

B -- 33-75 cm; Dark brown (7.5YR 4/4); loamy sand; weak coarse breaking to angular blocky and subangular blocky structure; very friable, non-sticky, non-plastic; common fine and moderate medium roots; few fine pores; diffused smooth boundary.

C1 --- 75-151 cm; Dark brown (7.5YR 4/4); loamy sand; weak coarse prismatic breaking to angular blocky and subangular blocky structure; very friable, non-sticky, non-plastic; few coarse and fine roots; few fine pores; diffused smooth boundary.

C2 --- 151-216 cm; (7.5YR 5/6); loamy sand; weak coarse prismatic breaking to subangular blocky structure; very friable, non-sticky, non-plastic; few fine roots; few fine pores.

C3 --- 216-398 cm; The same except it is weakly calcareous and thin strata, 7.5YR 5/4; sandy loam.

IIC4 - 398-434 cm; stratified materials of very fine silt and silt; 7.5YR 4/4 and 7.5YR 5/4.

Special Comments: Stratified sand and fine sand all the way to 15 feet deep. This summit is higher than the opposite summit.

Pedon 2

A 13% Foot slope position, concave.

A - 0-36 cm; Dark brown (10YR 3/3); fine sandy loam; weak granular to medium subangular blocky structure; slightly hard, slightly sticky, slightly plastic; common fine and medium roots; many fine pores; gradual wavy boundary.

B - 36-91 cm; Strong brown (7.5YR 4/6); loamy sand; coarse weak prismatic breaking to subangular and angular blocky structure; slightly firm, slightly sticky, non-plastic; common fine and few medium roots; few fine pores; diffused smooth boundary.

C - 91+; Strong brown (7.5YR 5/6); loamy sand; coarse weak prismatic breaking to subangular and angular blocky structure; very friable, slightly sticky, non-plastic; few fine and medium roots; few fine pores.

Comments: Surface finer texture is due to reworking by water and/or wind. White clear quartz through open channels in the second horizon. White quartz at root channels at the top of C horizon. In the shoulder position, sand and fine sand were present to a depth of 12 feet then followed by clay layer extended to a 15 foot depth, while the clay layer in the Fs position is shallower.

Ecotone 2E

Pedon 1

A 2% slope, summit, convex.

A1 - 0-13 cm; Dark brown (7.5YR 4/2); loamy fine sand; weak granular structure; friable, non-sticky, non-plastic; many fine roots; many coarse and medium pores; gradual smooth boundary.

B2 - 13-48 cm; brown (7.5YR 4/4); loamy fine sand; weak coarse prismatic structure; friable, non-sticky, non-plastic, many fine roots; many coarse and medium pores; gradual smooth boundary.

C1 - 48-240 cm; Brown (7.5YR 5/4); fine sand; single grain; friable, non-sticky, non-plastic; many medium roots; many coarse and medium pores.

C2 - 240+ cm; stratified, Brown (7.5YR 5/4 and 5YR 5/4); fine sand with lamellae and very fine sand; very friable, non-sticky, non-plastic; few fine and medium roots; many coarse and medium pores.

Pedon 2

A 19% slope, shoulder position, convex.

A1 - 0-10 cm; Dark brown (7.5YR 4/2); loamy fine sand; coarse weak granular structure; slightly hard, very friable, non-sticky; non-plastic; many fine and medium roots; many fine pores; gradual smooth boundary.

B2 - 10-43 cm; Dark brown (7.5YR 4/3); loamy fine sand; weak coarse prismatic structure; slightly hard, friable, non-sticky; non-plastic; many fine and medium roots; many fine pores; gradual smooth boundary.

C -- 43-200 cm; brown (5YR 5/4); fine sand; single grains; friable, non-sticky, non-plastic; many fine and medium roots; many fine pores.

Pedon 3

A1 ----- 0-15 cm; Dark brown (7.5YR 4/2); loamy fine sand; weak fine granular structure; slightly hard, friable, non-sticky; non-plastic; many fine and medium roots; many coarse and medium pores; clear boundary.

B2 ----- 15-57 cm; Dark brown (7.5YR 4/3); loamy fine sand; gradual weak prismatic structure; slightly hard, very friable, non-sticky; non-plastic; many fine and medium roots; many coarse and medium pores; gradual boundary.

C ------ 57-93 cm; Brown (7.5YR 5/4); fine sand; single grains;

slightly hard, loose, non-sticky, non-plastic; common fine roots; many coarse and medium pores; gradual boundary.

IIB21t - 93-200 cm; Reddish brown (5YR 4/4); clay loam; weak fine subangular blocky structure; slightly hard, slightly sticky, slightly plastic; few fine roots; many fine and medium pores; gradual boundary.

IIB22t - 200-225 cm; Reddish brown (5YR 5/4); clay loam; weak and fine subangular blocky structure; slightly hard, slightly sticky, slightly plastic; few fine roots; many fine and medium pores.

Pedon 4

A 3% slope, toe slope position.

A1 --- 0-10 cm; Dark brown (7.5YR 4/2); loamy fine sand; weak granular structure; slightly hard, friable, non-sticky, non-plastic; many fine and medium roots; many coarse and medium pores; gradual smooth boundary.

B1 --- 10-63 cm; brown (7.5YR 4/4); loamy fine sand; weak coarse prismatic structure; slightly hard, friable, non-sticky, non-plastic; many fine and medium roots; many coarse and medium pores; gradual smooth boundary.

B21t - 63-97 cm; Strong brown (7.5YR 4/6); clay loam; weak fine subangular blocky structure; slightly hard, slightly sticky, slightly plastic; few fine and medium roots; many fine and medium pores; gradual boundary.

B22t - 97-131 cm; yellowish red (5YR 4/6); sandy clay loam; coarse prismatic breaking to subangular blocky structure; slightly hard, friable, slightly sticky; slightly plastic; few fine roots; many fine and medium pores; gradual boundary.

B3 --- 131-200 cm; strong brown (7.5YR 5/6); sandy loam; weak coarse prismatic breaking to subangular structure; slightly hard, friable, non-sticky, non-plastic; few fine roots; many coarse and medium pores.

Ecotone 2W

Pedon 1

A 3% clope, summit position, convex.

A1 ----- 0-10 cm; brown (7.5YR 4/2); loamy fine sand; weak fine granular structure; loose, very friable, non-sticky, non-plastic; many fine and medium roots; many coarse and medium pores; clear boundary.

B2 ----- 10-36 cm; brown (7.5YR 4/4); loamy fine sand; weak coarse prismatic structure; slightly hard, very friable, non-plastic, non-sticky; common fine roots; many coarse and medium pores; gradual boundary.

C1 ----- 36-303 cm; brown (7.5YR 5/1); fine sand; single grains; loose, non-sticky, non-plastic; few fine roots; many coarse and medium pores; clear boundary.

IIB21t - 303-330 cm; Reddish brown (5YR 4/4); clay loam; weak and fine subangular blocky structure; slightly hard, slightly sticky, slightly plastic; few fine roots; many fine and medium pores; gradual boundary.

IIC2 --- 330-380 cm; yellowish red (5YR 4/7); gravelly fine sand; single grains; slightly hard, non-sticky; non-plastic;

few fine roots; many coarse and medium pores.

Pedon 2

A 7% slope; back slope position.

A1 ----- 0-15 cm; brown (7.5YR 4/2); loamy fine sand; weak fine granular structure; slightly hard, very friable, non-sticky; non-plastic; many fine and medium roots; many coarse and medium pores; clear boundary.

B2 ----- 15-94 cm; brown (7.5YR 4/4); loamy fine sand; weak coarse prismatic structure; slightly hard, very friable; non-sticky; non-plastic; common fine roots; many coarse and medium pores; gradual boundary.

C ------ 97-152 cm; brown (7.5YR 5/4); fine sand; single grains; loose, non-sticky; non-plastic; few fine roots; many coarse and medium pores; gradual boundary.

IIB21t - 152-175 cm; reddish brown (5YR 4/4); clay loam; weak fine subangular blocky structure; slightly hard, slightly sticky; slightly plastic; few fine roots; many fine and medium pores; clear boundary.

IIB22t - 175-193 cm; reddish brown (5YR 4/5); clay loam; weak fine subangular blocky structure; slightly hard, slightly sticky; slightly plastic; few fine roots; many fine and medium pores; gradual boundary.

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